Northumbria Research Link

Citation: Chen, Xiaohong (2019) Developing a third party investment partnership framework to encourage low carbon building projects in China. Doctoral thesis, Northumbria University.

This version was downloaded from Northumbria Research Link: https://nrl.northumbria.ac.uk/id/eprint/44097/

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: http://nrl.northumbria.ac.uk/policies.html

Northumbria University NEWCASTLE

CUSTOMER SERVICE EXCELLENCE CSE UniversityLibrary

Northumbria Research Link

Citation: Chen, Xiaohong (2019) Developing a third party investment partnership framework to encourage low carbon building projects in China. Doctoral thesis, Northumbria University.

This version was downloaded from Northumbria Research Link: http://nrl.northumbria.ac.uk/id/eprint/44097/

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: http://nrl.northumbria.ac.uk/policies.html

Northumbria University NEWCASTLE

UniversityLibrary

DEVELOPING A THIRD PARTY INVESTMENT PARTNERSHIP FRAMEWORK TO ENCOURAGE LOW CARBON BUILDING PROJECTS IN CHINA

XIAOHONG CHEN

PhD

2019

DEVELOPING A THIRD PARTY INVESTMENT PARTNERSHIP FRAMEWORK TO ENCOURAGE LOW CARBON BUILDING PROJECTS IN CHINA

XIAOHONG CHEN

A thesis submitted in partial fulfilment of the requirements of the

University of Northumbria at Newcastle for the degree of

Doctor of Philosophy

Research undertaken in Architecture and Built Environment

Faculty of Engineering and Environment

December 2019

ABSTRACT

Enormous potential carbon reduction from buildings can be achieved through adopting low carbon building technologies (LCBTs). However, investments in LCBTs in the private sector have been much lower than anticipated. This is due to a number of barriers such as high upfront costs, split economic interests, lack of finance, risk uncertainty and lack of practical knowledge. A Third Party Investment Partnership (TpIP) provides a risk and benefit sharing model for LCBTs investment in building projects. Typically, third party investors work with financing, constructing and operating the specialised LCBTs equipment through a long-term partnership with key actors of the LCBT adoption projects, providing quality and cost-effective low carbon products or services. However, there has been limited research and knowledge able to demonstrate how TpIP works, what makes TpIP successful, how TpIP perform in practice, and what incentives and benefits TpIP bring to its actors. The aim of this research is to develop a detailed and workable TpIP framework that encourages investment in private sector-led low carbon technologies in building projects in China.

Considering LCBTs technical and contextual influence deployment, this study focused on building-integrated photovoltaic (BIPV) projects in South China. Firstly, the study explored TpIP concept through literature review that identified critical drivers and barriers and key actors playing in the field of LCBTs investment. It then used expert forum method to contextualise the conceptual TpIP framework for China, and to identify a set of critical success factors (CSFs) that made TpIP successful in China. The CSFs were categorised into five aspects, representing financial, legal, operational, risk and external enabling conditions (FLORE), which were developed through a two-round expert interview process. The study further tested and developed the TpIP framework through case study method on three BIPV projects in South China. Finally, case study triangulation validated the final refined TpIP framework, which increased transferability and reliability of the study.

The research findings revealed that there are two forces and an agency within TpIP. The two forces, LCBTs Energy Production and Low Carbon Energy Market, are brought together by an agency, the Third Party Business, to make TpIP work. Case studies revealed that the production side of BIPV TpIP projects includes host,

contractors and capital. The market side of BIPV includes consumers, independent services and government. Energy management contracting is the third party investment business for rooftop BIPV. The study also revealed how these forces and businesses work together to achieve CSFs in all FLORE aspects. Moreover, the study revealed that the risk and benefit sharing TpIP framework overcomes the barriers and motivates the actors participating in LCBTs energy production to engage with the low carbon energy market.

This thesis made a number of significant and original contributions in the area of LCBTs investment and its implementation in the low carbon energy market. Firstly, it defined “TpIP” and developed a theoretical framework to demonstrate the principle within a TpIP. Secondly, it revealed the details of TpIP framework, including forces, actors and business, and how they act in practice towards improved BIPV performance through a third party investment business. Thirdly, it demonstrated a research method that can be used in developing innovative investment models within LCBTs building projects. Finally, it provided a better understanding of TpIP principles in the real world. The result of this study indicated that financial and operational dimensions are critical and that more attention should be paid to these in future research.

This study is not intended to develop a universal framework. However, the final TpIP framework and research methods would provide bases for future research in different contexts and settings.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

ACRONYMS AND ABBREVIATIONS

BAU - Business as usual

BIM - Building Information Modeling

BIPV - Building integrated photovoltaic

CNY - Chinese Yuan

CO_2 - Carbon dioxide

CSF - Critical success factor

CSR - Corporate social responsibility

DECC - Department of Energy & Climate Change (UK)

DPEG - Distributed photovoltaic electricity generation

DPV - Distributed photovoltaic

ECO - Energy Company Obligation (UK)

EMC - Energy Management Contract

EPC - Engineering, Procurement and Construction

EPC - Energy Performance Contract

EPI - Energy Performance Investment

ESCO - Energy Service Company

FiT - Feed-in Tariffs

FLOR - Financial, Legal, Operational and Risk

FLORE - Financial, Legal, Operational, Risk, External Enabling

GD - Green Deal (UK)

GDHIF - Green Deal Home Improvement Fund (UK)

GDP - Gross domestic product

GHG - Greenhouse gas

ICT - Information and communications technology

IEA - International Energy Agency

IPCC - Intergovernmental Panel on Climate Change

IRR - Internal Rate of Return

kW - Kilowatt

LCB - Low carbon building

LCBT - Low carbon building technology

NDRC - National Development and Reform Commission (China)

NEA - National Energy Administration (China)

O&M - Operation and maintenance

PAYS - Pay As You Save

PPA - Power purchase agreement

PPP - Public private partnership

PV - Photovoltaic

PVPA - Photovoltaic Poverty Alleviation (China)

ROI - Return on investment

SME - Small and medium-sized enterprises

TPI - Third Party Investor

TpIP - Third Party Investment Partnership

TPO -Third Party Ownership

UNEP - United Nations Environment Programme

WMO - World Meteorological Organization

WRI - World Resources Institute

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to my principle supervisor Prof. Paul Greenhalgh and second supervisor Prof. Niraj Thurairajah for their encouragement, supports, commitment and useful contributions which have greatly helped in the successful completion of this research. I am also grateful to my previous supervisors Prof. Srinath Perera, Dr. Lei Zhou, Dr. Nirodha Fernando and Dr Chika Udeaja for their contributions and advice towards the success of this research.

I appreciate all the respondents and Chinese companies participating this research. Finally, but perhaps most importantly I would like to thank my family for being so supportive. I would like to thank my sister Xiaodan who generously sponsor me to complete my study. Thanks to my Mum and my son for their love, support, patient and encouragement.

DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty Ethics Committee on 15th January 2013.

Word count of this thesis: 58,556 words

Name: Xiaohong Chen

Signature:

Date: 16/12/2019

Chapter 1 Introduction

1.1 Background statement

The building sector has a huge environmental impact. It contributes 36% of the global annual greenhouse gas (GHG) emissions and consumes nearly 40% of the world's energy (IEA, 2018). Its energy demand will grow rapidly alongside that of economic development, population growth and changing lifestyles. According to the Intergovernmental Panel on Climate Change (IPCC, 2014), buildings have the highest energy-saving potential compared to the other sectors. It is also the sector with the potential for the most cost-effective opportunities for GHG reductions. Most countries have set a low or net zero carbon building transition as a key pillar of their national strategic framework in tackling climate change. The UK has been a world leader in carbon reduction commitments. The UK government published the Code for Sustainable Homes to encourage all newly built houses to achieve zero carbon by 2016 (DCLG, 2006). In Germany, passive building technologies are spreading rapidly, while in France, the Grenelle de l'Environnement recommended that all new housing be passive or energy-positive by 2020 (UNEP, 2008). China announced its first carbon target just prior to the climate change negotiations held in Copenhagen (COP15) – a domestically binding carbon intensity reduction target of 40-45% relative to 2005 levels by 2020 (Xinhua, 2009). As the country is experiencing rapid urbanisation, with buildings increasing by more than 2 billion square metres every year, accounting for 50% of the world total (B. Qiu, 2010), the building industry will play an important role in helping China to achieve the promised emission reduction target (Li, 2008).

Although low carbon building is widely recognised as a key climate change strategy in most countries, and with the knowledge and proven technology to reduce carbon emissions from buildings being available, investments in the private low carbon building sector have been much lower than anticipated (IEA, 2008). This is due to a number of barriers such as higher initial costs, split economic interests, lack of project finance, risk uncertainty and lack of practical knowledge, etc. (UNEP, 2009). There are three main sources of funding for low carbon building technologies (LCBTs) investment: self-funding; government financial incentives; and third party investment.

Self-funding is the traditional way of building development, so property developers or building owners would invest in low carbon technologies as part of building costs. However, the high initial costs, low short-term return on investment (ROI) and misalignment between developers' costs and occupiers' benefits discourage developers from investing in LCBTs (Houser, 2009). Currently, government subsidies, grants and financial incentives are the main approaches to encourage investment in low carbon buildings (UNEP, 2009). However, these funds are far from enough compared to the market demand. The problems are currently exacerbated with the continuing economic recession and austerity measures to reduce public sector finance (Ritchie, 2011). This means that the third funding source, that of third party investment (such as investment by energy suppliers, venture capitalists or technology companies) is important for the future development of LCBTs. Typically third party investors install and operate renewable technologies and infrastructure for low carbon building projects, and they are willing to share the benefits with other parties involved.

Globally, third party investment in LCBTs has been carried out in many different ways. As yet there is no single model that fits all countries. A successful market-driven model will not only bring benefits to investors, it will also create millions of jobs by increasing the LCBT market, helping in the transformation towards to a low carbon economy (UNEP 2008). The launch of the Green Deal scheme by the UK government was an innovative framework for third party involvement. This new financial mechanism eliminates the need to pay upfront for energy efficiency measures and instead provides reassurances that the cost of the measures would be recovered by savings on the electricity bill. It is a flexible framework that provides businesses and consumers with the opportunity to make the energy efficiency improvements best suited to their situation. Millions of homes and businesses could benefit from improvements made under the Green Deal. Owner-occupiers and tenants will both be able to reap the rewards of better energy efficiency (DECC, 2010). Some other countries have also taken important steps to remove institutional and legislative barriers for independent renewable energy producers: Portugal, for example, simplified licensing for small renewable producers, while under a recent renewable energy law passed in the Philippines, renewable generators are to be given connection and transmission priority (UNEP, 2009).

China's LCBTs market has grown rapidly in the past two years. China produces the world's cheapest LCBTs such as photovoltaic (PV), wind turbine and solar hot water, and is the world's biggest manufacturer of this kind (REN21, 2009). There is a huge potential market for LCBTs application. China has introduced many new policies supporting the utilisation of LCBTs, for example, the policy to provide subsidies for building-integrated PVs (BIPV) for installations larger than 50 kW (REN21, 2009). The State Grid started to allow distributed PV solar power producers to be connected to the national grid free of charge from the 1st November 2012 (Juan, 2012). In 2013, the Government announced 14 new policies to promote the development of distributed PV electricity generation (CNE, 2014). Although these policies have helped to create a market condition for LCBTs investment in China, most projects are for public buildings that are led by government. There are few business models and market mechanisms to motivate project partners investing in private sector-led low carbon buildings (Qiu, 2009).

LCBTs investors need to be able to make profits to survive and continue to provide services. Different stakeholders are involved at the various stages in a building's life, making the partnering relationship more complicated with different economic interests and risks in terms of valuing investments in LCBTs (UNEP, 2009). The partnership between stakeholders under the third party investment model should be investigated and examined, incentives and benefits should be clearly identified in order to encourage a healthy and sustainable low carbon building market and help to prevent market failures. Limited academic research has been developed in this area; therefore, there is a need to develop a tested partnership framework and to research the details of a collaborative framework for low carbon building projects.

Private sector-led building and construction projects account for a significant proportion of overall property investments in both developed and developing countries (Johnson et al., 2013). In the United Kingdom, analysis by Gibson and Bamidele (2010) shows that in 2008, the private sector held nearly half of commercial, industrial and other non-residential buildings in terms of value. In China, the real estate sector is mainly driven by private sector investment. According to the Chinese Statistical Yearbook (2011), private sector investment accounts for 73% of the total fixed assets investment in the real estate sector in 2010. Data from the National Bureau of Statistics

(NBS, 2013) shows that Chinese private enterprises are the key players with 88% of the construction market, with a group of large state-owned enterprises (SOEs – mostly involved in infrastructure building) accounting for the rest. Carbon reduction in private sector-led building projects have an enormous impact on carbon reduction in the building sector. Furthermore, China's construction market is the largest in the world since 2010. According to the latest available figures, construction output value accounted for 26.4% of China's GDP in 2012 – a significant factor in the country's overall economic growth.

Due to the rapid expansion and population growth of cities in China, demand for residential and commercial buildings is growing fast. Although the State Council has not outlined a specific target to reduce carbon emission from buildings, the low carbon development of existing and new buildings is encouraged in China. The building energy efficiency standards have been raised, with more enforcement of these standards. The Energy Conservation Law, revised in 2018, required the development, design, construction or supervision units of construction projects to comply with the building energy efficiency standards. The C40's analysis of the emissions reductions required for cities shows low carbon buildings to be the most important policy in the urban environment in terms of emissions reduction potential (C40,2016).

1.2 Aim and Objectives of study

This research aims to develop a third party investment partnership framework that encourages LCBTs adoption in private sector-led building projects. This research focuses on building-integrated photovoltaics investment for south China.

The research is designed to pursue the following objectives:

1. To identify drivers and barriers for LCBTs investment in buildings in both global and China context

2. To explore third party investment models and draw lessons from successful examples of LCBTs adoptions around world

3. To identify and evaluate critical success factors (CSFs) that are applicable for low carbon building projects in China

4. To develop a conceptual partnership framework for China encapsulating CSFs, drivers and barriers representing key parameters within its thematic framework

5. To develop, test and validate a detailed third party investment partnership framework through building-integrated photovoltaics investment for south China

1.3 Scope of study

This research study focuses on third party investment models for LCBTs adoption in private sector-led building projects in China. Third party investment models, such as on-bill financing, power purchase or energy management contracts, use third party financing, construction and operation approaches to help property developers and owners to achieve low carbon building targets without upfront cost. LCBTs are energy efficiency or energy generation technologies that can be integrated and installed in buildings. Private sector-led building projects include residential, commercial and industrial buildings that have economic concern on development and operation costs, and do not rely on public funding. In order to develop a detailed and contextualised third party investment partnership framework, the scope of this study is set as follows:

- The study area is restricted to Southern China because of the following reasons: i) China has a vast territory that is divided into five main different climatic zones, economic zones and renewable energy resource zones. Restricting the study area to one climate zone can better serve local challenges for low carbon buildings. Southern China is in the Hot Summer & Warm Winter climatic zone. ii) It offers the researcher the best accessibility to LCB projects to obtain data in this region. iii) Availability of appropriate LCB projects for analysis. iv) The economy in Southern China is most prosperous and demand for LCB is greatest.

- The application of LCBTs in this study focuses on a rooftop PV electricity generation system because: i) Rooftop solar PV is growing remarkably fast in China, the PV industry receives strong support from central and local governments, the Government's 13th Five-year Plan aims to construct 100 demonstration zones of distributed solar PV by 2020. ii) Southern China is in a grade 3 solar energy zone with rich solar resource, which is suitable for distributed solar PV installations; iii) The declining cost and improved efficiency of solar PV makes it a profitable investment; iv) The financial subsidies have been gradually reduced for PV projects, there is a need for market-driven and benefit sharing business models to attract investments from the private sector.

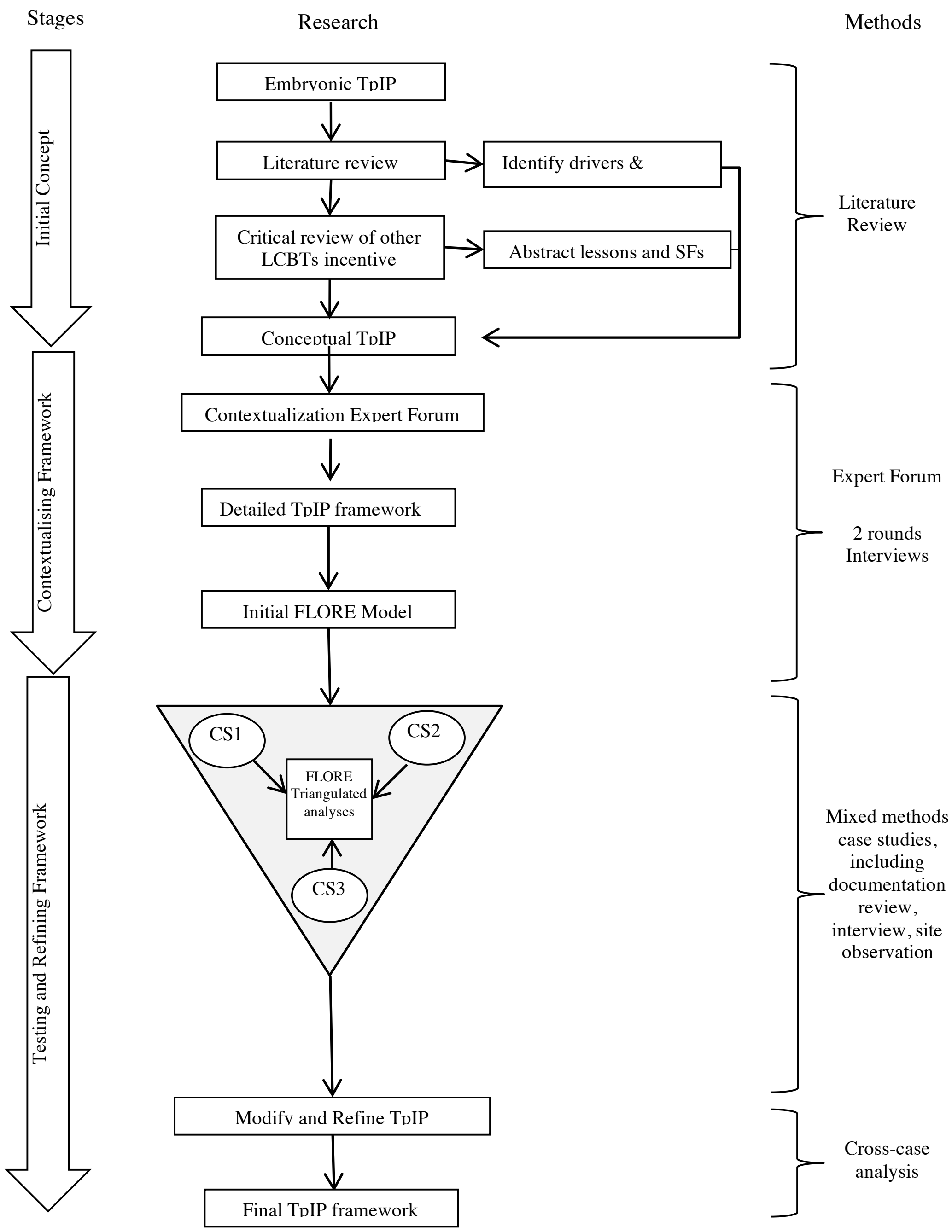
- The types of building selected for case study are industrial and commercial retrofit buildings. Industrial and commercial buildings in China usually have large rooftops with clear ownership, whereas urban residential buildings in China are normally multifamily block buildings without clear usage rights of the rooftop. In addition, China's electricity rates for industry and commerce are much higher than those for households. Thus, installing solar PV systems on industrial and commercial buildings has higher financial benefit than on residential buildings. Therefore, it is suitable for third party investment models.

- This study focuses on the business model/aspect of LCBTs investments, rather than from the view of technology and policy, although they are key factors for the success of investment business.

1.4 Research Design

This research is a qualitative exploratory study. The study consists of three stages. It firstly builds an initial conceptual framework from literature review. It then uses a two-stage expert interview method to develop a contextualised framework for China. Finally, a multi-case study approach is employed to test and refine the TpIP framework. The development of a final framework is based on building-integrated photovoltaics (BIPV) projects in South China. The outline of the research design is illustrated in Figure 1.1 below. It shows how the mixed research methods were used to achieve different objectives and outcomes.

Figure 1.1: Research Methods Outline



TpIP:	Third party Investment Partnership
LCBTs:	Low carbon Building Technologies
SFs:	Success Factor
FLORE:	Financial, Legal, Operational, Risk, External enabling
CS:	Case Study

1.5 Contribution and limitation of the research

1.5.1 Contribution to knowledge

The main contribution of this research is to develop a risk and benefit sharing partnership framework for adoption of LCBTs in building projects that encourages private sector investment. It will be the first private sector-led workable partnership framework applicable to low carbon building projects.

This research will also contribute to knowledge by identifying a range of drivers, barriers and CSFs of private sector-led low carbon building projects in China.

In addition, this research provides both internal and external transferability. The refined partnership framework can be applied to the same type of building projects. It can also be adopted as a framework for other types of building projects developed by other developers, researchers and the wider public.

Moreover, this study will provide evidence of real social benefits for property developers, owner-occupiers, tenants and project partners. It will also inform a wide spectrum of stakeholders and users including policy makers, academic institutions and financial institutes of the potential socio-economic benefits in the construction sector. As a result, it will benefit the environment by reducing carbon emissions and the risks of climate change.

1.5.2 Research limitation

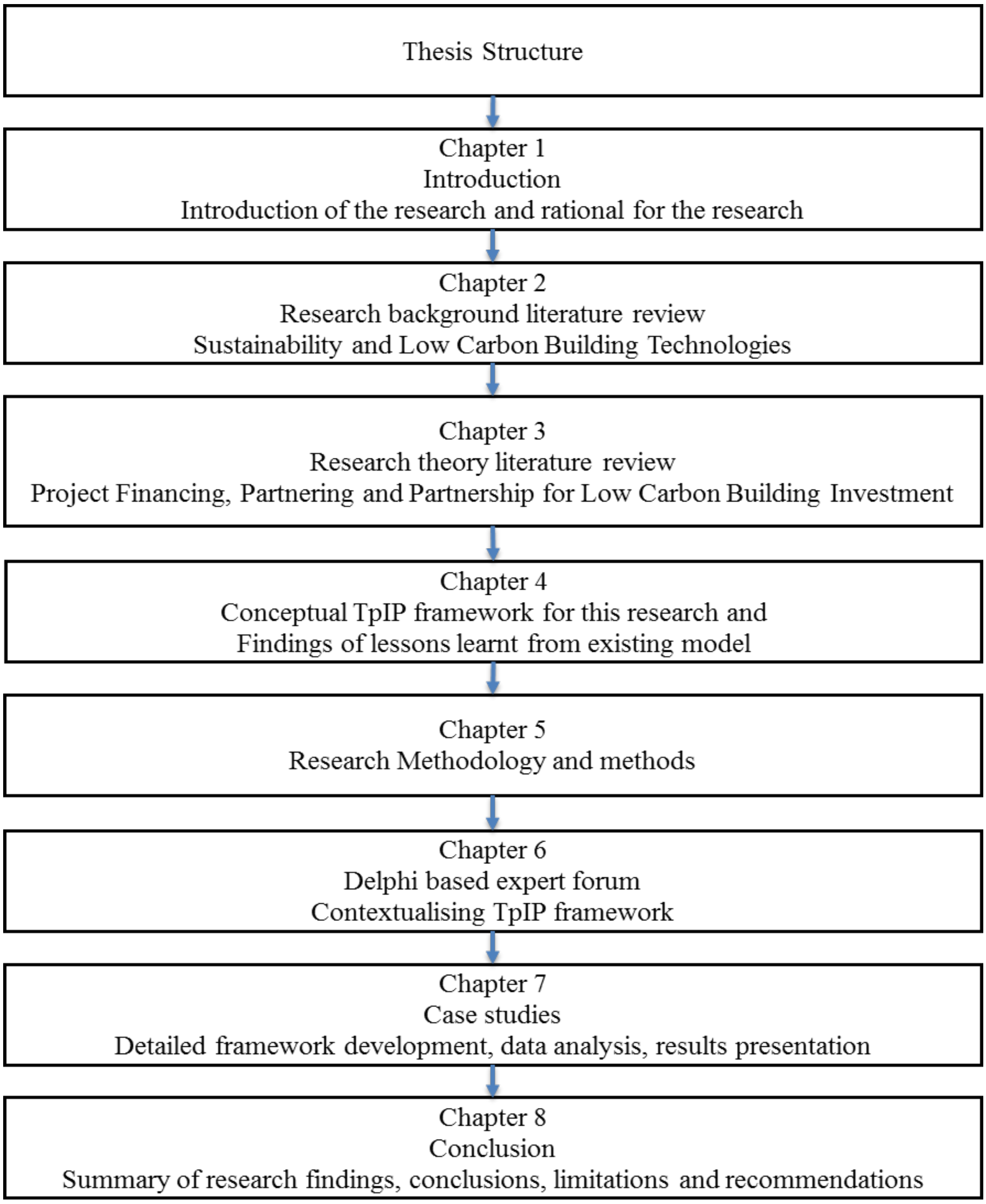
This research aims to develop a detailed and contextualized framework, rather than a generalised framework. The expert forum and case studies research method may be concerned with external validity and transferability to other contexts or settings (Herriott & Firestone, 1983; Patton, 1990). The research enhances its external transferability by using case study triangulation and multi research methods triangulation for final study results (Yin, 2009). Also by thoroughly describing the research context and assumptions it can provide base evidence to other researchers who wish to transfer the results to a different context and judge how efficacious the transfer is (Eisenhardt, 1989).

This research focuses its analysis to assessing the feasibility of LCBT project investment partnership models by considering the enabling CSFs on individual building projects in south China. The paper also considers technical, political or economic conditions, identifying their influence and roles within TpIP LCBT projects. Additional research is needed into the technical, political and financing conditions for LCBTs. In addition to the enabling influence of partnership investment in LCBs, success relies on critical factors that include technology availability, overall cost-effectiveness of energy efficiency and renewable energy measures, and the availability of financing structures in the local context. Further research is also needed into the implications of larger scale of the building stock, rather than individual buildings, by addressing LCBTs at the district or portfolio scale.

1.6 Structure of the thesis

This thesis consists of eight chapters. Figure 1.2 on the next page illustrates the structure and brief contents of these chapters.

Figure 1.2: Structure of this thesis



1.7 Chapter summary

This chapter outlined the research background, aim and objectives, scope, methodology, contribution and limitations. It also outlined the chapter structure of the thesis.

Chapter 2 Sustainability and Low Carbon Building Technologies

2.1 Introduction

This chapter reviews and explores the two fields of sustainability and low carbon technologies. It provides the research background and a theoretical foundation for this PhD research. In the field of sustainability, it first introduces the increasing global problems with scientific evidence, and then explores the definitions of sustainability and the principles of sustainable development. In the field of low carbon building, it investigates this topic through a comprehensive review of literature from concept, policies (especially in the UK and China), assessment methods of technologies, and finally, it explicates drivers and barriers of low carbon building technologies investment.

2.2 Global Challenges, Sustainability and Role of Building Sector

2.2.1 Global Challenges

In the past decades, humanity has been facing unprecedented global challenges such as climate change, resource depletion and energy crisis. The Intergovernmental Panel on Climate Change (IPCC) has come to a consensus through its scientific assessments on climate change that an increase in atmospheric concentrations of GHGs is the cause of global warming (IPCC, 2007, 2014). Although global warming was predicted by Swedish scientist, Svante Arrhenius, as early as 1896 (Arrhenius, 1896), it has only caught the public's attention since the 1980s. The World Meteorological Organization (WMO) produced a highly influential report in 1986, stating that greenhouse gases "are expected" to cause significant warming in the next century, and it recommended periodic assessments of the state of scientific understanding and its practical implications to further clarify the nature of the threat, and consideration of a global convention (WMO, 1986). IPCC's research by a group of scientists has proved that global warming can cause serious damage to the environment, such as a rise in sea levels and extreme weather. It is observed that the average sea level rose by 10 to 20 cm over the 20th century. An additional increase of 18 to 59 cm is expected by the year 2100. This will cause large problems for human communities living in low sea level regions (Susan, 2007). An estimate by WMO suggests that there could be more than 150 million refugees by 2050 due to climate change (WMO, 2009). About 20-30% of plant and animal species are at higher risk of extinction if the global average temperature goes up by more than 1.5 to 2.5°C. Scientists have observed that the atmospheric concentration of CO_2 had risen from pre-industrial (1750s) levels of 284 parts-per-million (ppm) to 300 ppm by 1950s, and reaching to 407.4 ppm in 2018 - the highest level in at least the past 800,000 years (NOAA, 2018). According to the National Research Council (NRC) of the US National Academies, "the past few decades have been warmer than any other comparable period for at least the last 400 years" (NRC, 2010). IPCC projected in its Fifth Assessment Report that over the 21st century the global surface temperature is likely to rise 1.5°C from the pre-industrial level for most scenarios, and is likely to exceed 2°C for many scenarios (IPCC, 2014). Sir Nicholas Stern (2007) pointed out that climate change is the greatest and widest-ranging market failure ever seen, presenting a unique challenge for economics. According to his report, benefits of strong early action on climate change far outweigh the costs of not acting. He concludes that unabated climate change could cost the world at least 5% of GDP each year, and under more dramatic predictions, the cost could be more than 20% of GDP. To avoid the worst effects of climate change, CO_2 emissions during the 21st century must reduce dramatically before the end of this century. The climate goal of the 2015 Paris Agreement is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C (UNFCCC, 2015). This requires global efforts in all sectors.

The quantities of GHGs, especially carbon dioxide, in the atmosphere have been driven up during one and a half century's industrialization, mainly through the burning of fossil fuels and destruction of forests. The growing world population and rapid urbanisation are the strong drivers behind the increasing global energy consumption. The size of the global population has more than doubled since 1950 – to 7 billion in 2011 - and is forecast to reach just over 9.3 billion people by 2050 (UNEP, 2010). City dwellers have a much higher carbon footprint than residents in rural areas. More than 50% of the global population now lives in urban areas. This figure is expected to increase with rapid urbanisation, particularly in Asia and Africa, which in turn leads to growing carbon emissions (Poumanyvong and Kaneko, 2010). According to forecasts, US$350 trillion will be spent globally on urban infrastructure and usage over the next three decades (UNFPA, 2007). If this investment follows "business as usual", humanity will use up its carbon budget for the next 60 years in just 30 years (WWF, 2010b; Höhne and Moltmann, 2009).

The world's economic development has depended heavily on energy since the industrial revolution in 19th century. The need for energy and its related services to satisfy human social and economic development, welfare and health is increasing. Fossil fuels, especially oil, coal and natural gas, are the backbone of the energy sector, despite the impressive efforts made in using energy from alternative sources. According to the Energy Information Administration (EIA) in 2007 fossil fuels counted for 86.4% of the total primary energy sources in the world (EIA, 2010). The latest BP Statistical Review shows that fossil fuel forms 87% of energy consumption, and only a tiny fraction of overall energy comes from "renewables" - just 1.6% (BP, 2012). Global demand for energy is rising fast as the population increases and developing countries such as China and India undergo dramatic economic growth. In the IEA New Policies Scenario, global energy demand will increase by one third from 2011 to 2035. World electricity demand will increase by more than two thirds over the period 2011-2035. Fossil fuels will continue to dominate the power sector, although their share of generation will decline from 68% in 2011 to 57% in 2035. CO_2 emissions from the power sector rise from 13.0 gigatonnes (Gt) in 2011 to 15.2 Gt in 2035, retaining a share of around 40% of global emissions over the period (WEO Factsheets, 2013).

In addition, the fossil fuels on which the world still depends are finite and far from environmentally friendly. Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being made. The production and use of fossil fuels raise concerns over resource scarcity. Even though there are debates about the peak oil and energy depletion theory, strong evidence has shown that fossil fuel-based economies have hastened ecological environment destruction (WWF, 2012). Furthermore, the enormous increase in the global demand for energy and limits on the rate of fuel production has created a bottleneck leading on several occasions to energy crises, which is known as a price shock, and has led to economic recessions (Engdahl, 2012).

Nevertheless, the Oil Crisis of the 1970s and past energy crisis incidents also led to greater interest in renewable energy and spurred development for many new alternative sources, such as solar, wind, tidal, biomass and geothermal energy, and new supporting legislation, as well as installation of these systems. According to IEA's estimates, renewables will account for nearly half of the increase in global power generation to 2035, and wind and solar photovoltaics would make up 45% of the expansion in renewables. However, energy-related CO_2 emissions will still rise by 20% to 2035. This leaves the world on a trajectory consistent with a long-term average temperature increase of 3.6°C, far above the internationally agreed 2°C target (IEA, 2013). To satisfy mankind's ever-increasing energy needs, all feasible alternative energy sources have to be considered.

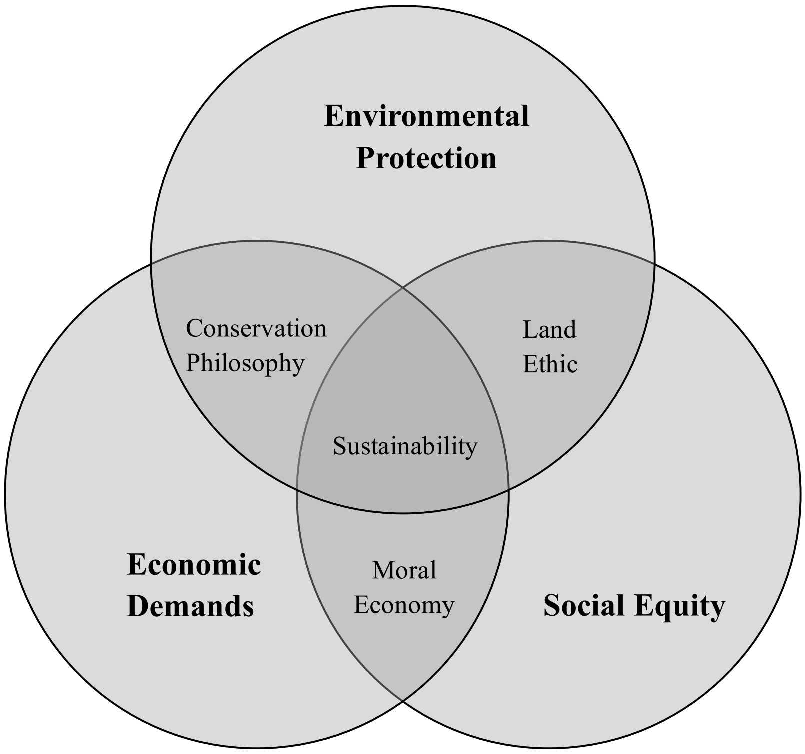
Clearly, the current system of human development, based on increased consumption and a reliance on fossil fuels, combined with a growing human population and urbanisation, is unsustainable. Forward-thinking governments and businesses have begun making efforts to mitigate these risks, for example by promoting renewable energy, resource efficiency, more environmentally friendly production and more socially inclusive development, for achieving sustainability.

2.2.2 Sustainability and Sustainable Development

The modern concept of sustainability, which also refers to sustainable development, started in the 1950s. Many publications, events and global initiatives have set the milestones for the evolution of the concept of sustainability. The publication of the book Silent Spring, written by Rachel Carson in 1962, represents a turning point in humanity's understanding of the interconnections between the environment, the economy and social well-being (IISD, 2012). Limits to Growth (Meadows, 1972) is another highly influential book that modelled the consequences of a growing population with finite resources. Though its methodology had many critics, the book significantly boosted awareness of environmental issues in the early 1970s. Ernest F. Schumacher (1979) in Small Is Beautiful described how small, appropriate and intermediate technology could empower people more and meet pressing social needs (DuBose et al., 1995). The UN Environment Programme Review in 1978 used the term “eco-development” emphasizing that environmental and developmental ideas needed to be considered concurrently. The World Conservation Strategy, which was launched internationally in 1980, was a major attempt to integrate the environment and development concerns under an umbrella concept of “conservation” (Mebratu, 1998). Since 1980, the United Nations (UN) has taken the lead on humanity’s sustainable development by bringing together social, economic, cultural and environmental issues and exploring global solutions. The concept of sustainability has spread from environmental protection activities to economic development strategies in all sectors. The definition of sustainability becomes wider and more and more complex. An enormous amount of literature has discussed the means of sustainable development from different angles. The definitions are varied and striking, even overlapping and conflicting (Barbier, 1987; Fezzey and Toman, 2002). Our Common Future by the World Commission on Environment and Development, also known as Brundtland Report (1987), provides a statement of sustainable development, which is the most quoted and accepted definition of sustainability - “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (Brundtland, 1987). This definition emphasizes the importance of human beings and offers an ethical principle for achieving equity between the intragenerational and intergenerational (Diesendorf, 2000). The concept of ‘needs’ in particular is about the essential needs of the world’s poor, to which an overriding priority should be given. The idea of ‘limitations’ imposed by the state of technology and social organisation on the environment’s ability should meet present and future needs. Moreover, this definition resolved the conflict between environment conservation and economic development, and strategically linked the issue of sustainable development to the global agenda of major issues.

The Three Pillars sustainability framework model introduced by Munasinghe (1993) has been used to guide and evaluate any action as truly sustainable development. The model as illustrated in Figure 2.1 consists of three intersecting and equally sized circles, representing a balance between environment, social and economic aspects and their interactions (Munasinghe, 1993). John Elkington (1999) originated the term Triple Bottom Line (TBL) for a sustainable business accounting framework which has been adopted by many organisations to evaluate their performance in a broader perspective to create greater business value.

Figure 2.1: The Three Pillars of Sustainability (Yates, 2012)



In addition to the three pillars model, in recent years, more dimensions have been included in sustainability models by some scholars. Meadowcroft (2000) emphasizes the institutional dimension of sustainable development, also referred to as "democracy" or "governance", as a fourth pillar in the model, revealing the importance of institutional change to merge environment and economics in decision making and to enforce the common interest through greater public participation, locally and internationally. Some advocates add culture as another separate dimension. Those opinions are essentially about emphasis and conceptualization (Gibson, 2000). Some literature also adds a time dimension to the model, representing intergenerational equity and to demonstrate the dynamics of the sustainability process over time (Lozano, 2008). In conclusion, sustainability requires the balance of environment, social equity and economic demands. These three interrelating spheres represent the essential aspects of sustainability models claimed by most advocates (Waas, Hugé, Verbruggen, & Wright, 2011).

However, in practice it is hard to keep all three dimensions in balance at all times. The sustainable development paradigm deals with difficulty and uncertainty and the field is incredibly complex. The world is still in a transition period towards the permanent correction of human activity. The most realistic feature is that environmental protection has to follow the economic principle, then provide benefits or financial returns to the economic activity, and maintain or not damage a stable human development. It is essential to develop a realistic approach of sustainable development to identify the key priority indicators in the particular context within the balance of environmental, social and economic conditions. As a greater focus on sustainability in wider and deeper research and practice, more specific sustainability frameworks and guiding principles have been developed according to local context and characteristics of sectors (Yates, 2012).

In September 2015, the General Assembly of the United Nations issued the 2030 Agenda for Sustainable Development that included 17 Sustainable Development Goals. It invoked that governments, industries and societies should work in cooperative partnership to achieve these goals.

It appears that the dominance of sustainable development in policymaking is giving way to climate governance, which could in turn have profound implications for the practice and politics of urban and regional development (While, Jonas, & Gibbs, 2010). The world is in an era where the reduction of greenhouse gases has become the new ‘master concept’ of environmental regulation (Keil, 2007). The 2015 Paris Agreement set a global goal to reach net zero emissions in the second half of the century (Paris Agreement, 2015). An increasing number of governments are translating that into national strategy, setting out visions of a carbon-free future. It is becoming the benchmark for leadership on the world stage.

2.2.3 Impact of the Building Sector

The building sector has the biggest influence and the most cost-effective potential to contribute to the global effort of sustainable development and climate change. According to the 2018 Global Status Report prepared by the International Energy Agency, the building sector contributes 36% of the global annual greenhouse gas emissions and consumes nearly 40% of the world's energy. The Fourth Assessment Report of IPCC (2014) shows that global final energy consumption in buildings grew about 5% between 2010 and 2017 due to strong growth in building sector activity and energy service demand. Under the IPCC's high growth scenario, building-related energy use and GHG emissions could double or potentially triple by mid-century to reach 15.6 billion metric tons CO_2 equivalent (IPCC, 2014).

IPCC (2014) recommended reducing GHG emissions by 50 to 85% below current levels to avoid the worst effects of climate change. Its Fifth Assessment Report shows that the building sector has the largest potential for significantly reducing GHG emissions compared to other major emitting sectors (IPCC, 2014). The International Energy Agency established a possible pathway for GHG reduction broken down by sectors along these goals. It estimates that the buildings sector alone will need to reduce annual CO_2 emissions by 8.2 billion tons below business-as-usual by 2050 (IEA, 2008). Harvey (2006) discussed that reductions in building energy intensity by 80% by 2050 will likely be necessary. Urge-Vorsatz (2007) concluded that by 2020 it will be possible to cut costs to approximately 29% of buildings-related global CO_2 emissions. The pursuit of low carbon buildings would be strategically essential to relieve the impact of global climate change (Chen et al., 2011).

In order to meet the commitment of the Paris Agreement, building sector energy-carbon intensities need to decrease to less than 20 tonnes of CO_2 per TJ before 2050 (IEA, 2017). This will require significant levels of investment in low carbon building technologies (LCBTs) and coordination between various actors (Abergel et al., 2017). Although market signals positively indicate increasing interests in low carbon buildings, the uptake in most developing countries, such as China, is still extremely slow. Low carbon buildings are commonly perceived to be more expensive than conventional buildings and often not worth the extra cost (Kats & Capital, 2003; UNEP, 2010). In China, there is little motivation for developers and house owners to invest in low carbon building and there is less engagement from low carbon product providers in building operation. The main reasons are that developers cannot see direct benefits from the extra cost of low carbon buildings, and low carbon facilities providers cannot easily access property markets under the conventional development model (Zhou, 2013). It is clear that the property sector uptake of LCBTs has been slow, regardless of other driving forces from the Government and society, and investment remains one of the biggest barriers (Zhou, 2013). Meanwhile, a wide range of mechanisms and initiatives has been demonstrated in several countries to be successful in overcoming the diverse barriers that hinder the implementation of low carbon building investments (Gouldson et al., 2015). Global investment in LCBTs is far from the required level, and it is necessary and urgent to develop appropriate market-oriented investment models, particularly for emerging countries, which can deliver a range of benefits to all actors and encourage them to join the low carbon transformation in the building sector.

Low/zero carbon building and sustainable building concepts play a leading role in mitigating energy consumption, which also reduce the amount of carbon emissions. Many countries have implemented new policies to reduce energy consumption based on building performance. Buildings represent a critical piece of a low-carbon future and a global challenge for integration with sustainable development (robust evidence, high agreement) (IPCC, 2014).

2.3 Low Carbon Building

2.3.1 Low Carbon Building Definition

There is much debate as how best to define a low carbon building, and there is no emissions threshold under which a building would qualify as a low carbon building in the existing definitions. Hestnes (2007) defines a low carbon building as "a building specifically designed and engineered with the intention to reduce CO_2". This definition does not give any specifications on the scope and period of carbon counting. It is a very vague and general concept. Li (2010) describes low carbon building as an architectural model that has low energy consumption, less pollution, low emission characteristics, minimizes greenhouse gas emissions in the whole life cycle of the building, while also providing reasonable comfort and use of space. This description covers a wide range of areas beyond carbon emissions from the building. It is also difficult to apply. Ramesh et al. (2010) defines low energy buildings as "the buildings having specific design that demand less operating and life cycle energy than if built according to conventional criteria with parity of all other conditions". He further defines a conventional building as a building built according to the common practice of a specific country. This definition gives a clear scope and period of carbon counting, together with a baseline of comparison. Isuadinso (2011) indicates that a low carbon building should emit significantly less GHG than regular buildings in order to meet the global goals of 80% carbon reduction. Since emissions from regular buildings vary a lot, depending on the building type and where it is located, and they are dynamically changing over time, expectations of carbon reduction of low carbon building are different from country to country. Many advanced countries and regions such as the UK, Germany, Sweden and California have set up zero carbon building targets, and give clear definitions for zero carbon buildings in their guiding documents (DCLG, 2008; UKGBC, 2008). Briefly, the ultimate goal of low carbon building is purposely designed and constructed to achieve little or zero carbon during their lifetime.

Although low carbon building is more specifically indicated as low carbon emission and high energy efficiency, it is included or interchangeable with the terms 'Sustainable Building' and 'Green Building' in many countries, such as the UK, USA, Canada and China. According to the US Environmental Protection Agency, green building is 'the practice of creating structures and using processes that are environmentally responsible and resource-efficient through a building's life cycle' (UNEP, 2010). The difference between low carbon building, sustainable building and green building is that low carbon building has a clearer indication of carbon emission reduction level; sustainable building includes two other pillars of sustainability: social and economic aspects; whereas green buildings normally address more environmental and human health issues, such as land conservation, material and water pollution, and indoor air quality, etc.

Further to various definitions, there is a large amount of guidance documentation available on what is required to design and construct low carbon buildings in practice, such as The Green Perspective by CIOB (2007), PassivHaus Primer by BRE (2008), Low Carbon Innovation And Delivery by RTPI (2009) and the Global Carbon Capacity Index – ZC2 by RICS (2009).

2.3.2 Low carbon building rating systems

In most countries, low carbon building is evaluated and certified through an assessment tool that validates its green and sustainability features (UNEP, 2010), and there are many assessment tools available worldwide, for example, LEED (Leadership in Energy and Environmental Design) in the USA; BREEAM (BRE Environmental Assessment Method), the Code for Sustainable Homes in the UK and the Green Building star-rating system in China.

Table 2.1 summarises the most well-known green building rating systems through a review of collected sources. The review shows that a total of 13 criteria relating to carbon emissions, sustainability and green building are used for evaluation, including: energy use; indoor environment / well-being; water; materials; transport; construction management / process; site selection / external environment; ecology; pollution; community; innovation; waste; regional context.

Table 2.1: Summary of Global Green Building Rating System (Author summarised from review of literature)

Green Building Rating Systems	Evaluation criteria	Levels	Sources
BREEAM (Building Research Establishment's Environmental Assessment Method) UK / 1990	Management, Health & Wellbeing, Energy, Transport, Water, Health, Ecology	Pass, Good, Very Good, Excellent	Building Research Establishment (BRE)
Code for Sustainable Homes UK / 2007	Six categories: energy/CO_2, pollution, water health and well-being, materials management, surface water run-off ecology and waste.	Levels from 1 to 6	UK Department of Communities and Local Government (DCLG).
LEED®(Leadership in Energy and Environmental Design) USA& Canada / 1994	Five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality	Certified (40%), Silver (50%), Gold (60%), Platinum (80%)	U.S. Green Building Council (USGBC)

Green Building Rating Systems	Evaluation criteria	Levels	Sources
Green Globes® USA& Canada / 2004	Seven key areas: Energy, indoor environment, site, water, resources, emissions, and project/ environmental management	One to four globes (1 = 35–54%, 2 = 55–69%, 3 = 70–84%, 4 = +85%)	Green Building Initiative (GBI)
Living Building ChallengeTM Canada / 2006	Seven performance areas: site, water, energy, health, materials, equity and beauty		International Living Building Institute (ILBI)
NABERS (National Australian Built Environment Rating System) Australia / 1999/2008	Nine areas: management, indoor environment, energy, transport, water, materials, land use, ecology, emission and innovation.	performance star rating 1-5	Department of Environment, Climate Change and Water
TQ Building Assessment System (Total Quality Building Assessment System) Australia / 2002	Site and equipment, Economic efficiency and technical quality, Energy and supply units, Health and comfort, Efficiency of resources	Scores	Austrian Sustainable Building Council
HK BEAM (Hong Kong Building Environmental Assessment Method) Hong Kong / 1996	site, water, energy, materials, indoor environmental quality, innovations and additions		HK BEAM Society
CEPAS (Comprehensive Environmental Performance Assessment Scheme) Hong Kong / 2006	Eight performance categories: Indoor Environmental Quality (IEQ), Building Amenities, Resources Use, Loadings, Site Amenities, Neighbourhood Amenities, Site Impacts, and Neighbourhood Impacts.	4 level labels: Platinum, Gold, Silver and Bronze	Buildings Department of Hong Kong
Three Star Green Building Assessment China / 2006	Land savings and outdoor; environment; Energy savings;	Stars from 1 to 3	Ministry of Housing and Urban-Rural Development

Green Building Rating Systems	Evaluation criteria	Levels	Sources
	Water savings; Materials savings; Indoor environmental quality; Operations and management		
CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) Japan / 2004	Building Environmental Quality and performance and Building Environmental Loadings	Spider web diagram, histograms and BEE graph	
GRIHA (Green Rating for Integrated Habitat Assessment) India / 2007	Evaluates the sustainability of a building holistically over its entire life cycle	Stars from 1 to 5	Tata Energy Research Institute
HQE (High Environmental Quality) France	14 targets of the environmental quality of buildings		Association pour la Haute Qualité Environnementale (ASSOHQE)
Protocol ITACA GBTool Ttaly / 2006	Site, Consumption of the resources, environmental Loads, environmental Quality indoor, Quality of the service, social - economic Aspects	Rating 1-5	Sustainable Building Council Italia
DGNB Germany / 2008	Environmental, economic, sociocultural and functional aspects, technology, processes and site	Gold, Silver and Bronze	German Sustainable Building Council

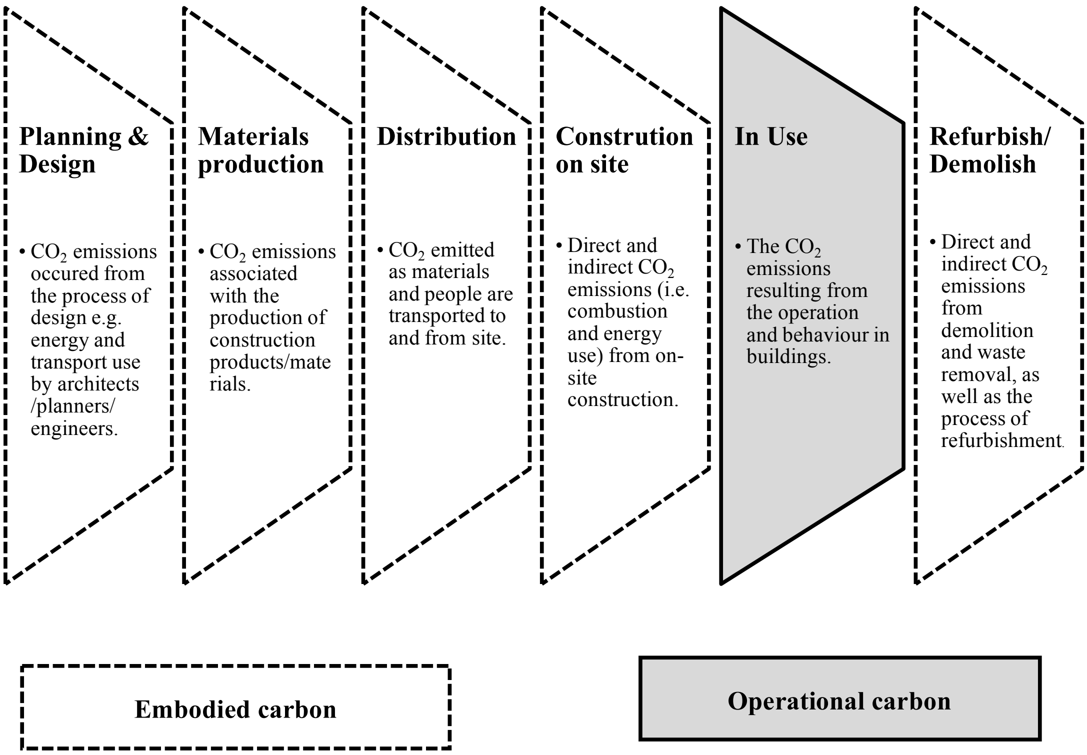
2.3.3 CO_2 emissions from buildings

Understanding the CO_2 emissions during the life cycle of a building can help in taking a holistic view of low carbon building, and choosing the most effective LCBTs.

CO_2 emissions from buildings primarily arise from their consumption of fossil fuel-based energy, both through the direct use of fossil fuels and electricity that has been generated from fossil fuels (Ramesh, Prakash, & Shukla, 2010). Various processes and materials have direct and indirect impact on the environment, and significant GHG emissions may be generated in different phases of a building's life. All these phases should be considered in order to minimize the life-cycle primary energy use and CO_2 emission of a building (Sartori & Hestnes, 2007).

According to a 2010 report from the UK's Department For Business Innovation & Skills (BIS), the whole life cycle of the building process can be divided into six broad areas, which are illustrated in Figure 2.2 below with associated CO_2 emissions.

Figure 2.2: Carbon emissions from broad areas of building's life cycle, (Author altered from source: BIS, 2010)



Dakwale and Ralegaonkar (2011) describe the total CO_2 emissions from a building in two types: embodied carbon and operational carbon. Embodied carbon is sequestered in building materials during all processes of production, on-site construction and final demolition and disposal. Operational carbon is expended in maintaining a comfortable indoor environment through processes such as heating and cooling, lighting and ventilation appliances.

Chen et al. (2011) have developed an assessment framework for low carbon buildings with the introduction of systems carbon emission indicators and detailed carbon emission account procedures for the life cycle of buildings. Nine stages of building construction, fitment, outdoor facility construction, transportation, operation, waste treatment, property management, demolition and disposal for the life cycle of buildings are considered.

Dakwale (2011) concluded through case study research that the operating energy of the buildings has the largest share in life cycle energy distribution. It was calculated from 60 case studies from 17 countries that operating energy has the major share (80–90%) in life cycle energy use of buildings followed by embodied energy (10–20%), whereas demolition and other process energy has negligible or little share.

A large amount of literature shows that operational carbon emissions (in-use building emissions) account for the largest proportion of total CO_2 emissions during the whole life cycle of a building (BIS, 2010). The analysis of 50 Norwegian building cases found that life cycle energy use of buildings depends on the operating (80–90%) and embodied (10–20%) energy of the buildings (Winther, 1999). The Green Construction Board (2013) estimate that carbon emissions from regulated energy use in buildings for the reference year 2010 to be 139 $MtCO_2e$. The most significant source of carbon emissions in the built environment is domestic direct emissions from space heating (e.g. oil and gas boilers), followed by non-domestic space heating (GCB, 2013).

The energy use and carbon emissions in both residential and commercial buildings in Canada, USA and the EU shows that the single largest use of energy is for space heating, followed by water heating. Space heating is also the single largest use of energy in commercial buildings, accounting for up to two thirds of total energy use. Lighting is sometimes the largest single use of electricity in commercial buildings, although in hot climates air-conditioning tends to be the single largest use of electricity (ürge-Vorsatz, Danny Harvey, Mirasgedis, & Levine, 2007).

Some studies found that sometimes the life cycle energy of the self-sufficient building is more than some of its low energy versions. This is due to the fact that, in the case of some self-sufficient houses, though operating energy is zero, embodied energy is so high that exceeds the life cycle energy of some of the low energy cases. Thormark (2006) reported that embodied energy and its share in the life cycle energy for low energy building is higher than conventional ones. Dakwale (2011) suggests that carefully designed low energy buildings perform better than self-sufficient houses in the context of life cycle. Too many technical installations in order to make a building self-sufficient may not be desirable.

2.3.4 Low carbon building technologies

A building's life cycle energy demand can be reduced by reducing its operating energy significantly through the use of passive and active technologies, even if this leads to a slight increase in embodied energy. In the design process, low carbon building products should widely use solar, wind, geothermal and other renewable and clean energy sources to reduce energy consumption. In the construction process, the building should use low-carbon technologies and materials and minimize energy consumption and carbon emissions. In the use phase, the building should aim to change lifestyle habits and consumer attitudes, use energy efficient air conditioning, lighting and energy-saving appliances, extend the life cycle of the building and household items and reduce carbon emissions (Fan & Hao, 2012).

Several examples of LCBTs are reviewed and grouped through a comprehensive literature review of academic literature and professional documents. The collective LCBTs can be divided into six categories: Low carbon building materials; Passive design measures; Energy efficient equipment and appliances; Renewable Energy; and Carbon offset / sink (see Table 2.2).

Table 2.2: Type of LCBTs and Reference Sources

Category	Examples of Technologies
Low carbon building materials (Minimizing the embodied energy of buildings)	Sustainably sourced natural and bio-based products derived from natural materials, such as soil, thatch/leaves, bamboo, hemp, mud, stone, etc. Recycled materials from mining waste, building waste, industrial waste and by-products, such as fly ash blocks and rubber aggregates Prefabricated and modular building components
Passive design (Utilising solar, wind and water)	Passive solar heating and cooling technologies, such as trombe wall, thermosyphoning, solar chimney Daylighting devices, such as light tube and reflecting board Sun shading devices Energy-free natural ventilation techniques Breathable windows Passive evaporative cooling system
Passive Design (Building envelope)	Thermal mass Insulation (walls and roofs) Hollow core slab High performance glazing
Energy-Efficient Equipment and Appliances	High-efficiency HVAC Boilers, Heat Recovery Intelligent control system Lighting control sensors Energy-saving lift Energy-efficient lighting LED (Light-emitting diode) Temperature and humidity independent control (THIC) system Radiant heating and radiant cooling systems Chilled beam and ceiling

Category	Examples of Technologies
Renewable Energy	Solar thermal Solar PV Micro-wind Ground-source heat-pumps Micro combined heat and power (Micro-CHP) Biomass heating Micro-hydro Fuel cells Biofuel Anaerobic digestion from waste Geothermal energy Air source heat pump
Carbon offset / sink	Roof garden Vertical green walls

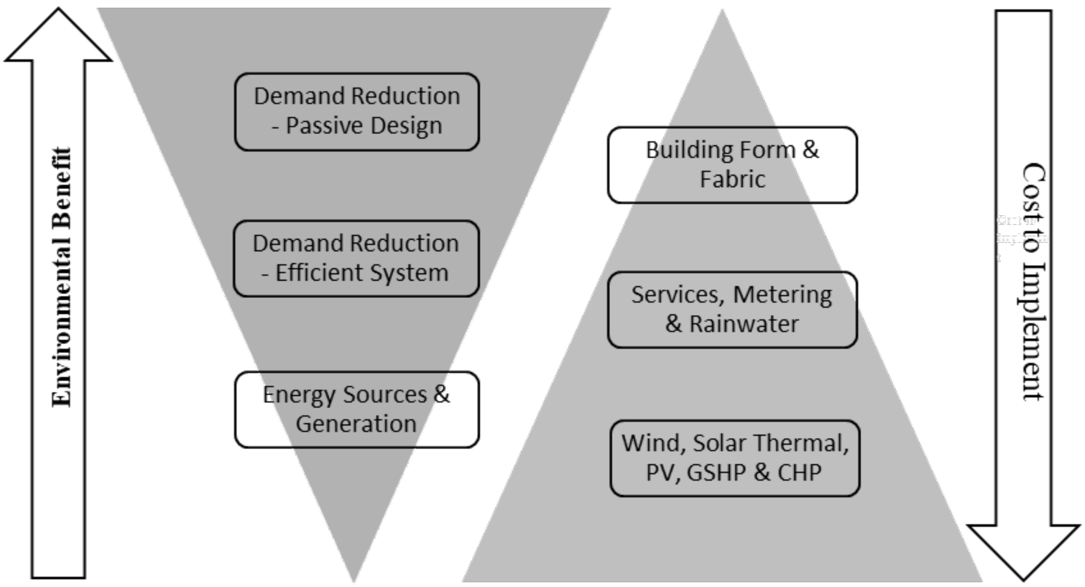
Alternative low carbon building materials can be used to replace conventional energy intensive materials, and such technologies can result in a considerable reduction of embodied energy (~50%) (Reddy, 2004). Passive building technologies include utilising solar, wind and water energy, and creating a building envelope. Various passive techniques and energy saving strategies can reduce the interior temperature and increase thermal comfort, reducing air conditioning loads. Many passive technologies greatly depend on the climatic conditions. Energy-efficient equipment and appliances have become more widespread in recent years, and these include efficient heating and cooling equipment, as well as lighting, appliances and optimal control systems, etc. Renewable energy technologies include a wide range of renewable sources, some of which are state-of-the-art technologies, and some have been widely adopted in buildings. Carbon offset/sink technologies are included, although this category accounts for a very small proportion of the total CO_2 emissions of a building. Roof gardens and green walls are common features for green buildings, and they also have combined functions such as shading and insulation.

The above mentioned LCBTs are a concise review of new and advanced technologies for low carbon buildings. This review is by no means exhaustive, as it omits some of the less influential areas and measures. For instance, low carbon building construction measures are not reviewed here. Please see Appendix A: Table of LCBTs for a review of LCBTs.

Apart from the above-mentioned LCBTs, carbon reduction in buildings can be achieved through architectural design, for example in passive design approaches such as an atrium and sun space, and direct daylighting. This study does not focus on the architectural perspectives of low carbon building.

Figure 2.3 below illustrates the LCBTs hierarchy for Low carbon building and their relative weights in Environmental benefits and Cost to implement.

Figure 2.3: Low carbon building design hierarchy (Author's own)



Reducing the demand for energy and generating clean energy are the key approaches for low carbon buildings. Passive design is the most cost-effective and high energy-saving strategy for low carbon building, therefore, should be considered first. Low carbon energy sources and generation contribute relatively less carbon reduction, as the technologies usually have a high cost with long-term return, hence, should be the last step when passive design and efficient systems have been implemented (Isiadinso, Goodhew, Marsh, & Hoxley, 2011).

2.3.5 Drivers of LCBTs

Although there is a broad range of cost effective LCBTs technologies that are widely accessible, the diffusion of LCBTs has been very slow, especially in developing countries.

There are many perceived benefits to adopt LCBTs, but the two key drivers can be simply identified as: Government Incentives and Market Demand. Currently, government intervention has been seen as the biggest driver for the low carbon building market, through a range of methods, such as setting restricted building regulations, tax, policies and providing financial incentives (UNEP, 2010).

On the other hand, the market demand for low carbon buildings is increasing. A recent survey from McGraw Hill (2013) discovered that now green building is a business imperative around the world. Business drivers such as client and market demand are key factors influencing the market. There are two main reasons for the increasing low carbon building market demand: the first is the price drop of renewable energy technologies, for instance, solar photovoltaic technology has shown significant development in recent years, with ongoing technological improvements and capital cost falling. By the end of May 2011 nearly 80,875 solar PV installations in the UK had received support through the Feed-in Tariff (FiT) scheme (DECC, 2011; Young, 2011). The second is the increasing awareness of the risk of climate change and the impact of the building sector on the environment (N. H. Stern, 2007). More and more occupiers, developers and investors are changing their behaviour and preference to demonstrate their corporate social responsibility. In addition, low carbon buildings also have the potential to demonstrate long-term savings, particularly through annual energy cost reduction and increasing the property value. Nelson, Rakau, and Dörrenberg (2010) have identified that operating costs for LEED-certified buildings are 8-9% lower than for regular buildings. McGraw Hill's survey in 2013 also mentioned that global industry professionals had high expectations of the operating cost benefits of green building — 19%believed their operating costs would decrease by 15%or more over the next year (51%believe there will be increases of 6%or more), and 39%believed they would see savings of 15%or more over the next five years.

These are the associated benefits of LCB development. However, because of the global economic recession, government incentives shrank, dampening the conversion to greener buildings (Nelson et al., 2010), for example, the financial crisis in Europe is causing governments to implement austerity measures, and support for public and/or ratepayer funding of PV incentives is falling.

2.3.6 Barriers of LCBTs

Although the market signals positively indicate the increasing interestin low carbon buildings, the uptake in most developing countries, such as China, is still extremely slow. Low carbon buildings are commonly perceived to be a lot more expensive than conventional buildings and often not worth the extra cost (Kats & Capital, 2003; UNEP, 2010). Kats (2003) identified certifying LEED Platinum will have a 6.5% higher cost compared with traditional buildings. Another barrier is that the incentive for building owners and building tenants to improve energy efficiency, make green improvements and seek or maintain third party certification are often misaligned (UNEP, 2010). In China there is still little motivation for developers and house owners to take action on low carbon building investment and less engagement from low carbon product providers in building operation. The main reasons are that developers cannot see direct benefits from the extra cost of low carbon buildings, and low carbon facilities providers cannot easily access the property market under the conventional development model (Zhou, 2013).

Even in developed countries, such as the UK, there are still barriers to increased adoption of LCBTs. The Carbon Trust (2005) classified the barriers into four main categories: real market failures; financial costs/benefits; behavioural/organisational non-optimalities; and hidden costs/benefits. Moreover, Abdel-Wahab identified a clear knowledge gap in the area of performance of LCBTs that informs the decision-making processes in his research on the adoption of LCBTs by Housing Associations (Abdel-Wahab, Moore, & MacDonald, 2011).

It is clear that the property sector has been slow to adopt LCBTs, regardless of other driving forces from the Government and the social sector, and the investment problem remains as one of the biggest barriers (Zhou, 2013).

Meanwhile, a wide range of mechanisms and initiatives has been demonstrated in several countries to be successful in overcoming the numerous, diverse and strong barriers that hinder the implementation of low carbon building investments.

2.3.7 Low carbon building development in China

China is the world number one carbon emitter. The Chinese government announced its carbon target to reduce carbon intensity by 40-45% relative to 2005 levels by 2020 (Wen, 2009). The Government plays a leading role in the development of green building in China. The first national standard on green building evaluation - Evaluation Standard for Green Building (GB/T50378-2006) - was introduced in China in 2006. Although there was only 21% of evaluated green building implemented in 2007, the figure reached 82% in 2008. According to statistics, there are 243 projects which have obtained the “Evaluation Standard” certificates up to September 15 2011. Considering China’s huge amount of building stock, the green buildings account for less than 1% of the total amount (Qiu, 2009).

According to China’s building regulation, the country is divided into five climate zones and the economic developments are different among different regions. The green building development levels are also uneven. Local standards or regulations of green building evaluation based on “Evaluation Standard” were produced. However, they have not yet been extensively applied (Tian, 2012).

In order to encourage the development of green building, the “Program for the Development of Chinese Green Building” was issued by the Ministry of Housing and Urban-Rural Construction in May 2011. The encouragement policies of “reward replace subsidy” are carried out thoroughly. There are some incentive policies for the application of low carbon building technologies, particularly for distributed PV electricity generation in recent years, such as fit-in-tariff.

China’s LCBTs market has grown rapidly in the past two years. China produces the world’s cheapest LCBTs such as photovoltaic (PV), wind turbine and solar hot water, and is the world’s largest manufacturer of this kind (REN, 2009). There is a huge potential market for LCBTs application. China has introduced many new policies supporting the utilisation of LCBTs, for example, the policy to provide subsidies for building-integrated PV (BIPV) for installations larger than 50 kW (REN 2009). The State Grid started to allow distributed PV solar power producers to be connected to the national grid free of charge from the 1st November 2012 (Du, 2012). In 2013, the Government announced 14 new policies to promote the development of distributed PV electricity generation (CNE, 2014). Although these policies have helped to create a market condition for LCBTs investment in China, the most projects are public buildings that are led by government. There are few business models and market mechanisms to motivate project partners investing in private sector-led low carbon buildings (Qiu, 2009).

2.4 Summary

Humanity is facing unprecedented global challenges in climate change, environment degradation and energy shortages. The latest report of the Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming is caused by atmospheric increase in greenhouse gases (GHG), which is primarily human-induced (IPCC, 2007, 2013). GHG emissions from fossil fuels will continue to rise as energy demand increases. In the International Energy Agency's (IEA) new policies scenario, global energy demand will increase by one third from 2011 to 2035. Fossil fuels will continue to dominate the power sector, although the share of renewables in total power generation is forecast to rise from 20% in 2011 to 31% by 2035 (IEA, 2012, 2013). In addition natural resources including fossil fuels are finite. According to the Global Ecological Footprint Network, human beings are consuming resources and polluting the planet at a level 50% higher than the earth can renew or absorb (GEF 2013). This has caused environmental problems such as carbon emissions, deforestation, water scarcity and overfishing. The Living Planet Index shows there has been around a 30% global decline in biodiversity health since 1970 (WWF 2008, 2012). In the meantime the human population is growing fast, reaching 7 billion in 2011 and is forecast to reach just over 9.3 billion people by 2050 (UN, 2010). The global urban population will almost double to 6 billion by 2050 (UNFPA, 2007). There is urgent need to avoid a carbon-locked urbanization model as industrialised countries have been doing, slowing the dangerously rapid consumption of finite resources and moving towards renewable energy sources.

The building sector has a huge environmental impact. It contributes up to 30% of the global annual greenhouse gas (GHG) emissions and consumes up to 40% of the world's energy (WBCSD, 2008). These emissions are mainly related to the use phase of buildings. Buildings have the highest energy-saving potential compared to other sectors. It is also the sector with the potential for the most cost-effective opportunities for GHG reductions (IPCC 2007). Many countries have already taken steps towards low or zero carbon buildings. Emerging economies such as China are experiencing rapid urbanisation, with buildings increasing by more than 2 billion square metres every year, accounting for 50% of the world total (Qiu, 2010), with the building industry playing an important role in helping China to achieve the emission reduction targets (Li, 2008). Although low carbon building is widely recognised as a key climate change strategy in most countries, the knowledge and proven technology to reduce carbon emissions from buildings being available, investments in the private low carbon building sector have been much lower than anticipated (IEA 2007). This is due to a number of barriers such as higher initial costs, split economic interests, lack of project finance, risk uncertainty and lack of practical knowledge, etc. (UNEP, 2009).

Chapter 3 Low Carbon Building Investment Models

3.1 Introduction

This chapter discusses the potential for implementing LCBTs on building projects through innovative project financing methods. It discusses low carbon building finance and investment, and introduces the initial concept of a third party investment model and identifies the thematic framework for this study.

Section 3.2 and its sub-section define the TpIP concept and terminology applied in this study. It explains a typical TpIP stakeholder relationship model, compares it with a traditional self-funding model and illustrates the changes of the stakeholder network structure between them. It then reviews three different third party investment models that have already been used on low carbon building projects around the world. By analysing their features and mechanisms, this section identifies the common characteristics and differences between them. Furthermore, it discusses the lessons learnt from these models.

Section 3.3 explains what type of TpIP framework this study seeks to develop, including the scope and considerations of the framework, how the TpIP framework may vary between countries and other terminology applied to the TpIP concept.

Finally, section 3.4 summarises the concept of TpIP discussed in this chapter and outlines some key issues for the development of a TpIP framework, including its scope and considerations.

3.2 Financing Low Carbon Building

Research shows that the costs of addressing environmental damage after it has occurred are usually higher than the costs of preventing pollution or using resources in a more sustainable way in the first place. It has already been shown in Chapter 2 that the building sector has the most cost-effective opportunity compared with other major sectors (IPCC, 2007; N. H. Stern, 2007). According to UNEP FI's report "Universal Ownership" released in 2011, the annual environmental costs from global human activity amounted to US$ 6.6 trillion in 2008, equivalent to 11% of GDP. Under a "business-as-usual" scenario, annual global environmental costs are projected to reach US$ 28.6 trillion, equivalent to 18% of GDP in 2050. The report also found that external costs caused by companies can reduce returns to investors (UNEP, 2011). In China, apart from pollution, natural disasters and ecosystem degradation alone account for 200 billion yuan loss in GDP each year with an annual increase rate of 9% (MEP, 2008). Sadly, very few Chinese banks realize that environmental costs are becoming increasingly financially material even without regulations like the Green Credit Policy (Qiu, 2009).

Stern's review (2007) suggests that the scale of existing deployment incentives worldwide should increase by two to five times, from the current level of around $34billion per annum. The recent report from the World Bank (2013) stated that there is a huge gap in financial investment in renewable energy and warned that governments and businesses must double or even triple investment in new clean sources of energy, double global renewable energy capacity and double energy efficiency by 2030. Meanwhile renewable energy accounts for just 18% of the global energy mix, compared to the 36% objective for 2030. In China, there are 2 billion m^2 new buildings being built every year, meaning the need to invest in low carbon building is urgent, and the current financial gap is huge (UNEP, 2011, World Bank, 2013).

The purpose of property development in the private sector is to make a profit from the process of development (March, 2009). Private developers operate as investors who make their money from selling or renting the property they develop. They may also develop the property for their own occupation and use. The finance required for development is usually 'short-term' money, which is needed to cover all the costs incurred in purchasing the land, and in the design and construction process. This may be paid back shortly after completion if the development is sold on and a profit made. If capital cost and maintenance are separated because the developer is selling on, then it is likely that as the developer is only concerned with the profit made on the capital cost of the building, low carbon and energy efficiency issues will not be at the top of the agenda (Drury et al., 2012).

Innovative financial models for LCBTs projects need to meet the principles of project investment and finance if they are to survive and continue to provide services (Eichhammer, Ragwitz, & Schlomann, 2013). For example, in the United States, the new project finance structures emerged primarily in response to the opportunity presented by long term power purchase contracts available from utilities and government entities. These long term revenue streams were required by rules implementing PURPA (The Public Utility Regulatory Policies Act, US), the Policy resulted in further deregulation of electric generation and, significantly, international privatization following amendments to the Public Utilities Holding Company Act in 1994. The structure has evolved and forms the basis for energy and other projects throughout the world.

3.2.1 Existing Financial Types

To gain a better understanding of investment in low carbon building projects, it is vital to identify the existing financial types and analyse their benefits and risks. Table 3.1 illustrates four types of investors for LCBs: Government, Financial Institution, Developer/Owner and Third Party.

Table 3.1: Financial types for low carbon building projects

No.	Investors	Main Building Types
1	Government	Public Office Buildings, Social Housing, Schools, and Hospitals,
2	Financial Institution	Commercial Building, Social Housing
3	Developer/Owner	Residential Buildings, Commercial building, and Industrial Building
4	Third Party	All types of Buildings

3.2.1.1 Government-driven model

Government has two main economic tools to encourage low carbon building development. Firstly, it could provide financial incentives to encourage the development of low carbon buildings; secondly it could provide funding to encourage more demonstrated building development or the retrofitting of existing buildings. The Green Deal scheme offered by the UK government is an optional solution to remove the barriers (DECC, 2012). The Green Deal provides finance for investment in energy efficiency measures with no upfront cost to households or businesses, with finance secured as a charge on the property to be repaid through the electricity bill over a period of up to 25 years. The Green Deal business model is designed to suit the market situation in the UK where there is a large proportion of poorly insulated existing housing stock that needs significant energy efficiency improvement.

Another financial tool is carbon tax; for example the climate change levy in the UK will be a taxable supply of specified energy products for use as fuels for lighting, heating and power, which is applied to non-domestic users.

3.2.1.2 Market-driven model

According to UNEP, the financial sector plays four roles in promoting LCBs: owner/user, investor or private developer, lender and insurer (UNEP, 2010). Under current economic circumstances, the financial sector plays a critical role in lending money for low carbon building projects - for example, the Institutional Investors Group on Climate Change (IIGCC) is the world's largest institutional funder, which focuses on investment practice associated with climate change. It contains 80 European institutional investors, including some of the largest pension funds, and it represents around $7.5 trillion in assets.

Developers and occupiers seek more socially conscious investments. They focus more on responsible real estate and use low carbon building, either to demonstrate their corporate social responsibility or as a unique selling point to enlarge their profit margins. For example, China's largest property developer, Vanke, collaborating with BRE, built the Beijing Green Park by using the concept of BRE's Innovation Park in

Watford, UK (BRE, 2012), and by doing so they may increase their project's uniqueness and competitiveness compared with other property developers in China.

3.2.1.3 Performance-based model

Third Party investors (commonly the Energy Service Company or the consultant firm) offer to provide the project finance, to install and operate renewable technology and the infrastructure for low carbon building projects and share the benefits with other parties. An Energy Service Company (ESCO) is a professional business, offering consumers the opportunity to reduce their energy consumption and the related costs through a wide range of energy services. This range may include energy analysis and audits, energy management, project design and implementation, maintenance and operation, power generation and energy supply, monitoring and evaluation, facility and risk management. Below are some contract examples typically provided by an ESCO.

Energy Performance Contracting (EPC) - an external organisation implements a project to deliver energy efficiency or a renewable energy project. The approach is based on the transfer of risks from the client to the external organisation, and the payment is based on the performance of the project.

Energy Services Agreements (ESA) - third party entities negotiate ESAs, arrange/provide capital, develop power plant projects (typically renewable energy) and manage installed equipment for large industrial and commercial projects. The SPE (Special Purpose Entity) is capitalized by third party investors and finances the costs of the efficiency improvement. The host signs an ESA with a project developer and agrees to pay either a fixed or floating rate for the energy savings received. A floating rate is equal to a percentage (e.g. 80%) of their actual utility rate. A fixed payment is based on a cost per avoided energy basis. The host agrees to make payments for the contractual terms of their agreement (e.g. 5-15 years). During this period, the SPE retains ownership of the installed equipment and returns cash flows to investors. This structure enables energy efficiency to be treated as a service and an off-balance sheet transaction.

Third-party ownership - many residential and commercial customers like the idea of having distributed solutions on their property, but many do not want the hassle of installing, operating and maintaining the systems themselves. Additionally, many customers do not have the upfront capital required to purchase new devices (State and Local Energy Efficiency Action Network, 2014). In the solar industry, third-party ownership models, such as power purchase agreements (PPAs) or leasing programs have been developed to address these issues. In these schemes, developers install solar panels, which they continue to own, operate, and maintain, on customers' properties. In a PPA model, the solar developer sells power generated from the system to the host customer at a fixed rate over a 15–20-year period (Strupeit and Palm, 2015). PPAs have accelerated the distribution of solar technologies by providing long-term revenue streams that decrease the capital-intensive investment risk of many projects (Alagappan et al., 2011) and have become the main method for financing large commercial and institutional solar systems (Coughlin and Cory, 2009). Leases are often used in places that do not have PPA regulations and are similar to PPAs except that the property owner leases the system instead of entering into a PPA (Strupeit and Palm, 2015).

3.2.2 Practices in the UK

The UK is recognised as a global leader in the development of policies, designs and technologies in the area of green and low carbon building. Table 3.2 summarise the financial models in the UK that have been used for the applications of LCBTs. Each of these models has advantages and disadvantages. They are normally designed with and accompanied by other policies.

Table 3.2: Innovative LCBTs finical investment models in the UK

Models	Descriptions	Reference source	Project type
Green Deal	The Green Deal is the UK government initiative that is designed to help business and home owners to employ more green technologies in their properties. The idea is that installing new green technology into existing property with no upfront costs. Occupants will pay back the costs through energy bill over a period of time. GD is unlike a conventional loan because if the tenants move out of the property the bill stays with the property where the savings are occurring and not with the bill payer.	http://www.greendealinitiative.co.uk/	Retrofit building
ECO	The Energy Company Obligation (ECO) is the UK Government's new domestic energy efficiency programme which has replaced the existing CERT and CESP programmes, both of which come to a close in 2012. ECO works alongside the Green Deal to provide additional support for packages of energy efficiency measures. ECO also provides insulation and heating packages to low income and vulnerable households and insulation measures to low income communities.	https://www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills/supporting-pages/energy-companies-obligation-eco	Retrofit building
Feed-in-Tarriff	Feed-in tariffs (FITs) are also known as Standard Offer Contacts, Feed Laws, Minimum Price Payments, Renewable Energy Payments, and Advanced Renewable Tariffs.	(Couture & Gagnon, 2010)	Renewable electricity

Models	Descriptions	Reference source	Project type
Green Investment Bank	The UK Green Investment Bank is the first bank of its kind in the world, with £3 billion of funding from the UK Government to invest in sustainable projects. the flagship scheme is to encourage private sector money into low carbon technology and green initiatives	http://www.greeninvestmentbank.com/	New and existing building
Community ownership	Projects can be 100% community owned, or may be developed under co-ownership arrangements with the private sector	(Walker, 2008)	Community
Energy Performance Investment	An **EPI** is a funding solution that enables entities (the end beneficiary) to acquire Energy Conservation Measures (ECM) via a third party investor and pay for them from the financial value of the proven energy savings achieved using a pay-as-you-save mechanism. Should no financial saving be achieved then the end beneficiary has nothing to pay		Existing building
PFI	Under the PFI model, the public sector contracts to purchase quality services on a long-term basis to take advantage of private sector management skills and to have private finance at risk. Compared with traditional methods, the PFI model could provide a higher profit rate for the private sector in the long term (normally a PFI contract lasts for 25-30 years) and better partnership with the public sector.	(Zhou, Ramin, & Kurul, 2013)	Public buildings, infrastructure

However, issues of cost, investment and ownership, and technical risk still provide disincentives to the uptake of LCBTs. The UK government has adopted a number of approaches to encourage these new and often expensive technologies, including energy price subsidies, capital grants and supply side obligations (Day, 2009). In recent years, financial models have tended to move from grants reliance to a market-driven type (Peretz, 2009). Further review on models in the UK and other countries will be studied and analysed in Section 2.2.2 of this Chapter.

3.2.3 The Challenges and Drivers in China

China is the largest carbon emitter in the world. The building sector consumes a quarter of the country's total energy. China has 40 billion m^2 of existing building store, 99% of which are energy-inefficient buildings. In the past 20 years, building energy consumption in China has been increasing at more than 10% per year (World Bank, 2008). The challenge faced is that the rapid increase in new buildings and household appliances requires more energy (Cai, 2008).

China consumes: 8% of the oil consumption; 40% of the cement; 31% of the coal; 25% of the aluminium. The output is only 5% of the world GDP.

Buildings consume 27.6% of the total energy. Building material consumes another 16.7% of energy. 2 billion m^2 new buildings were erected in 2003, but only 5% with energy-saving performance, with a further 20 billion m^2 expected to be built in the coming 15 years. Large quantities of energy will be needed in future.

The need for China to develop green building is unquestionable, and in recent years the Chinese government has taken a number of dynamic policy initiatives in this area, such as the Three Start Rating and Golden Sun Programme. In the meantime, China has also become the world manufactory for green building technologies, such as solar photovoltaic and wind turbine products.

China's LCBTs market has grown rapidly in the past two years. China produces the world's cheapest LCBTs, such as photovoltaic (PV), wind turbine and solar hot water, and is the world's biggest manufacturer of this kind (REN, 2009). There is a huge potential market for the application of LCBTs. China has introduced many new policies supporting the utilisation of LCBTs, for example, the policy to provide subsidies for building-integrated PV (BIPV) for installations larger than 50 kW (REN, 2009). The State Grid started to allow distributed PV solar power producers to be connected to the national grid free of charge from the 1st November 2012 (Du, 2012). In 2013, the Government announced 14 new policies to promote the development of distributed PV electricity generation (CNE, 2014). China has implemented FiT policy for distributed PV energy since 2013, resulting a sharp increase of PV installations in domestic market. Although these policies have helped to create a market condition for LCBTs investment in China, the most projects are public buildings that are led by government. There are few business models and market mechanisms to motivate project partners investing in private sector led low carbon buildings (Qiu, 2009).

Currently, specific low-carbon policies are not a priority in the China's policy system. The relative policies are mainly associated with some administrative measures, such as "command-control", which hinders the development of a low-carbon economy. SONG and LU (2009) suggest that low-carbon economy policy in China should follow the market-oriented reform process and the policy design should be changed from relying on administrative means to relying on market mechanisms (DAI, 2009).

In China, the Government has issued a series of laws, including the environment protection law, the cleaner production promotion law, the pollution prevention law and the reproducible energy law. In terms of energy saving and discharge-decrease, the Government has set various objectives in a plan named “Eleventh Five Year Plan”, by stipulating three obligatory indices: reduction of energy consumption per unit of GDP by 20%, reduction of water consumption per unit of GDP by 30% and reduction of total major pollutants emission by 20%, and an anticipated index: comprehensive utilization rate of industrial solid waste increasing by 4.2% compared with the 2005 index (NBSC, 2007). The enforcement of these laws is expected to halt environmental deterioration whilst maintaining economic growth. In line with these efforts, China has elevated the status of the State Environmental Protection Bureau (SEPB) to The Ministry of Environment Protection for the purpose of improving the effectiveness and efficiency in dealing with the severe challenge of environmental protection (MOEP, 2008). In addition, the former Ministry of Construction (MOC) has issued the

Green Building Evaluation Standard and the Green Construction Guideline (GCG) which provide an assessment framework for green buildings and a framework for green construction respectively (MOHURD, 2007).

Qi (2010) identifies the drivers for the adoption of green construction practices from the contractors' perspective as being managerial concerns, government environmental regulations and stakeholder pressures.

In the case of building integrated renewable energy projects, a number of partners will be required to undertake the following, either on a contract basis or as part of a Special Project Vehicle (SPV) partnership:

- Project finance via Equity Subscription Agreement(s) with project partners
- Loan Agreement with a lender
- Technical Support Agreement with a consultancy to provide project development advice
- Energy Services Agreement including sale of electricity, heat (and possibly chilled water) to buildings or Power Purchase Agreement with the local electricity grid
- Engineer, Procure, Construct (EPC) Agreement with a suitable contractor ideally on a turnkey lump sum basis
- Fuel Supply and Ash Disposal Agreements
- Operation and Maintenance Agreement

It may be possible to combine a number of the above functions into a single contract or partnership with the property developer for the Finance, Design, Build, Operation and Maintenance (FDBOM) of the energy project, but this will be dependent on the market's appetite for the associated risks and whether the developer would prefer a more hands-on involvement in the selection and management of suppliers for each project element.

The links between the energy policy framework, financing and implementation of renewable energy and energy efficiency projects have to be strengthened, and capacity building efforts are required. Off-site production is fragmented and dominated by relatively small companies with little effective coordination or partnering with major contractors.

3.3 The concept of third party investment model

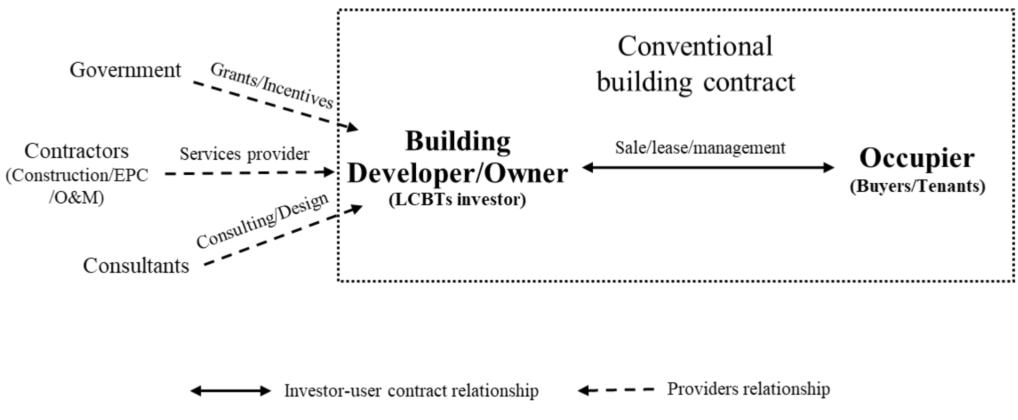
The third party investment concept is not a new idea. There are several similar models and initiatives that have already been used on low carbon building projects around the world. The above sections have reviewed a number of well-established models in the UK and China, including the Green Deal Scheme and Private Finance Initiative (PFI) in the UK, Energy Performance Investment (EPI) for energy conservation measures. This section provides more examples from other countries, particularly the USA. Despite the many differences between the countries, they have used similar approaches, i.e. a third party investment, to address major barriers such as high upfront cost, split incentives and high risks, and a common objective to drive the decision actually to undertake LCBs and upscale the market. However, each model is designed for special challenges faced by the host countries. Therefore, they are not interchangeable. By reviewing these models, the study learns from the policies, structures and procedures used in these models, analyses their common characteristics and CSFs, and identifies components that could be used to develop a TpIP framework for the purpose of this study.

3.3.1 Defining TpIP for this study

This study uses the term *Third Party Investment Partnership* (TpIP) to define a concept in which a LCBT application on a building project is funded, installed and operated by a third party, rather than fully self-funding by the property developer or the owner of the building in a business-as-usual (BAU) property development. The "third party investor" (TPI) referred to in this study could be an energy service company, venture capitalist, low carbon technology supplier, joint venture, new established company for this purpose or another type of entity. The project "Host" is the adopter party, either a commercial property developer or a self-build property owner who adopts LCBTs in their buildings. The "Occupier" is the end user of the property, who may be a tenant or a buyer. The host and the occupier may be the same party in the case of a self-build and self-use building project. The purpose of TpIP is to release a part of or the whole financial burden and responsibilities from the host party, and to transfer these to the third party when high upfront costs and high risks are the major barrier for adopting LCBTs, and at the same time to share the benefits brought by the LCBTs application among all stakeholders. Implementing alternative LCBTs reduces carbon emission from buildings, reducing the risk of climate change. Studies have shown that improving building energy performance can lead to higher market values of those buildings. It also provides healthier and a more productive environment to the users of the building (The Greenage, 2016). More jobs and green GDP are generated to support the local economy.

The relationships between the stakeholders are established through a variety of contractual agreements. The most common stakeholders in a LCBTs building project are developers, owners, investors, financiers, government, contractors, operators and users. They interact with each other within a set of legal agreements and contracts. Figure 3.1 demonstrates a typical BAU LCBTs investment stakeholders relationship model, in which the building developer/owner bears the risks and responsibilities throughout all stages of LCBTs development.

Figure 3.1: A typical BAU LCBTs investment stakeholders relationship model (Author's own)

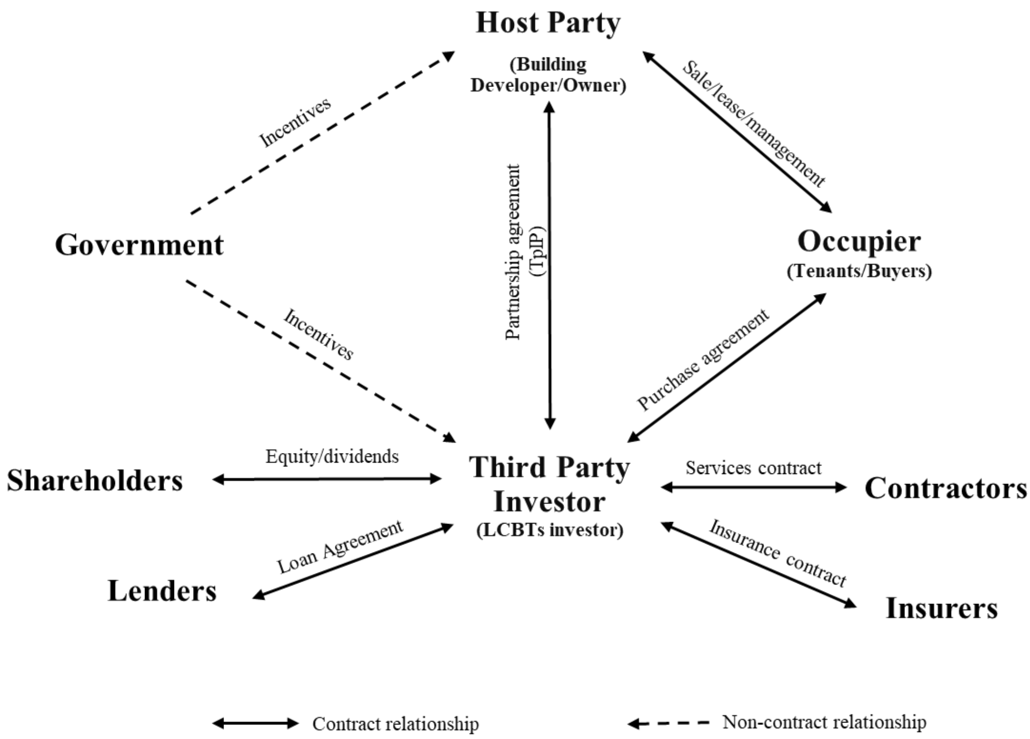


Note: EPC= Engineering, Procurement and Construction; O&M= operation and maintenance

The contractual agreements between developer/owner and buyer/tenants are conventional building transaction contracts, i.e. sale, lease and/or management contracts. According to network theory (Chowdhury, Chen, & Tiong, 2011), the developer/owner holds the core position in the BAU network model.

In contrast with the above BAU model, in the TpIP model, some or all LCBTs' costs, risks and responsibilities are transferred to the TPI. The TPI, the host and/or the occupier arrange, balance and share the responsibilities via partnership agreement. From the viewpoint of the network, the TPI holds the central position in this model. Figure 3.2 shows a typical stakeholders relationship model for the TpIP LCBTs investment.

Figure 3.2: A typical TpIP LCBTs investment stakeholders relationship model (Author's own)



The Partnership model has a number of features which suggest that it could be effective in stimulating consumer demand and in encouraging business investment in LCBTs projects delivery (reference). A successful partnership will be heavily dependent upon the terms of the negotiated contract with the third party investor. Thus, the effectiveness of the Partnership model will become clear when the market is tested and terms are agreed, and when the LCB project delivery takes place.

However, there is not a one-size-fits-all-model, because of the complexity and specificity of construction projects. Figure 4.2 aims to illustrate a general concept of TpIP at an earlier stage of the study. A detailed shape of the delivery framework will be tested and refined depending on the type of building and the project context. Thus, this study aims to develop a detailed partnership framework after investigating, developing and evaluating it in real life industrial practice during the course of this research.

3.3.2 Lessons learnt from other similar models

3.3.2.1 Selecting similar models

In this section, the study analyses and compares three models, namely: the Green Deal (GD), Third Party Ownership (TPO) and Energy Performance Investment (EPI) to identify their features and useful lessons. By reviewing these models, the study seeks to learn from their characteristics and mechanisms, understand the context of policies, structures and procedures used in these models, so that the useful elements for developing a TpIP framework for the purpose of this study can be identified.

The reasons to select these models are because they:

- are well-established and have large potential growth; although Green Deal has not delivered the level of success that was expected, the scheme is well documented and has attracted much attention, and there is much to learn from the scheme for this study;

- use third party financing mechanisms for the initial costs of LCTBs installation, which falls within the criteria of TpIP descripted above;

- aim to use market-based solutions to attract investment from the private sector for LCBTs adoption, which meets the purpose of this study;

- use formal contracts for long-term collaboration, which provide tangible a legal framework for study;

- represent established business models, reduce investment risks and make business sustainable;

- are initiated from different countries, and by analysing the enabling conditions and context, this study can identify the usefulness and appropriateness of relevant lessons.

More detailed features of each models are discussed in the sections that follow.

3.3.2.2 Green Deal (GD)

GD, also known as the "Pay-As-You-Save" (PAYS) scheme, is a UK government initiative that targets low carbon retrofit of UK housing stock. The scheme provides initial funding for households to install energy efficiency measures and pay back the cost through their energy bill over a period of time (DECC, 2012). According to the Committee of Public Accounts' report (2016), GD has provided £50 million loans to 14,000 households since its launch in 2013, far less than DECC's initial projection of £1.1 billion target (House of Commons, 2016). Due to "low take-up and concerns about industry standards", the GD scheme was ended following the Government's announcement of no further public funding to GD in July 2015 (DECC, 2015). However, the framework set for GD continues to serve the existing GD plans and to support any private finance provider willing to enter the market (DEIS, 2017).

One of the key features of GD is using an "on-bill financing" mechanism to overcome the barriers of high upfront costs and split incentives for LCBTs adoption. On-bill financing is a loan financing mechanism that allows the property owner to install a certain set of LCBTs without initial payment, and the financial provider collects repayment through electricity bills. GD loans attach to the property energy bill payer instead of the owner, if the current bill payer moves out or sells the property, the remaining repayment is passed to the next bill payer (DECC, 2012). Electricity bill payment is considered as a long-term stable cash flow, which eliminates the investor's risk of not recouping the investment (add ref). However, the drawback of this arrangement is that it may discourage owners to take up GD if they do not intent to occupy the property long term (add ref).

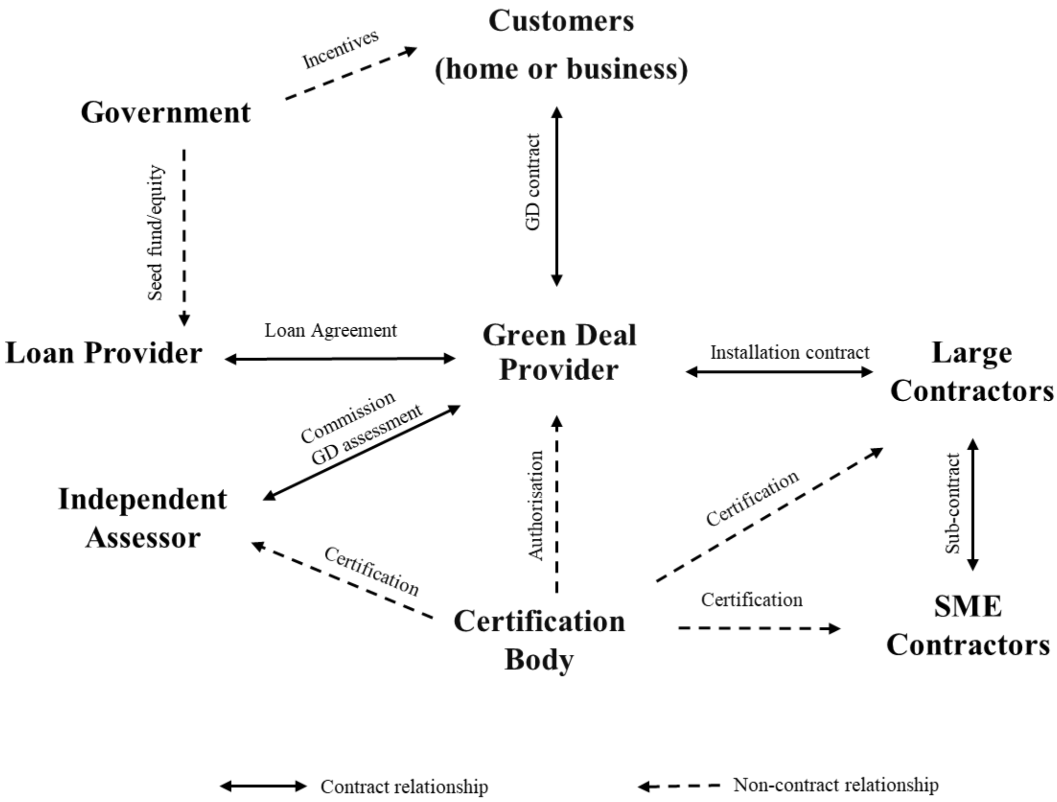
Another key feature of GD is that the projects must meet the "Golden Rule" policy, which means repayments do not exceed the monthly savings in energy costs. After the improvement has been made, the properties need less energy to run than they would have without the installation of chosen LCBTs, and these savings are used to repay the loan (DECC, 2012). This rule is to ensure a net saving for consumers after adding repayments onto their energy bills. It has been argued that the Golden Rule is one of the reasons for the low take-up of GD (Rosenow, 2016). Many properties and measures are rejected in the first place simply because that they do not produce enough savings to meet the rule. In addition, the maximum amount of finance that can be lent to a household is determined by the estimated energy saving. More expensive measures that may be better suited to PAYS are excluded. Rather than being able to finance with little or no upfront cost, those potential improvements just did not happen in practice (Rosenow, 2016).

GD is designed to be a private sector lead model that stimulates investments in the low carbon retrofit market without government subsidies. Private funding is the main source of GD loans to cover the upfront cost of energy efficiency measures. A government-backed GD framework would allow lending to consumers at preferential interest rates that would encourage both investors and property owners to enter into deals for installing energy efficiency measures. It uses market-based solutions to keep the private sector as the key driver for its success (O'Keeffe, Gilmour, & Simpson, 2016). Studies have shown that ultra-low interest rates are a key success factor to encourage people to take up pioneered loan schemes, such as German infrastructure banks that provide a 1% interest rate for building energy efficiency improvements (Rosenow, 2016). By contrast, the average interest rate of a GD loan is 7.5% (DECC, 2012), which is not attractive for the majority of the market. This leads to low uptake of GD loans, consequently GD private funds made a loss on lending (Gillich, Sunikka-Blank, & Ford, 2017).

Government subsidies are still the key driver of GD uptakes. In fact, the GD was supported by the Green Deal Home Improvement Fund (GDHIF cashback scheme) and the Energy Company Obligation (ECO). The analysis from DECC (2014) shows that government financing support (ECO and Cashback Scheme) helps GD uptake. During the first year of GD start-up between 2013 and 2014, there was only a slight growth in GD applications and plans. Since October 2014, the number of applications tripled with more than 10,000 on-going finance plans and applications with a value of about £40m (UCL GDFC lecture). Nevertheless, the launch of GDHIF, which worked in line with GD Finance, led to a high uptake of GD plans from the levels experienced in the previous year.

In addition, the GD framework provides a set of legislative, operational guidelines. The GD certification mechanism provides accredited assessments and installations; as shown in Figure 3.3 below, GD participants include the GD provider, GD advisor, GD assessor, GD installer, certification body and GD authorities. In the GD process, the GD provider plays a central role.

Figure 3.3: A typical Green Deal stakeholders relationship model (modified by Author from source)



Types of GD projects:

GD is designed mainly for low carbon refurbishment of existing buildings. However, there are a few new built building projects using the GD scheme. It has also been applied to community projects (Marchand, Koh et al., 2015)

Lessons learnt from the Green Deal:

- GD is a government-backed scheme, which enables the GD process. The Government set up a legislative, commercial and contractual framework, providing tools and guidance to GD participants. The GD accreditation process ensures customers contract with trusted GD suppliers. The Government's promotion and additional financial support are critical drivers for GD take-up.

- A low interest rate is a key success factor to encourage people to use the loan scheme for upfront costs. Many papers criticize the fact that GD's interest rates are too high (refs). Viable financial models and low risks on non-repayment are key factors to attract private investors.

- GD should address customer demand in the framework design and promotion. GD survey (DECC, Ref) shows that customer's interests are more focused on the building comfort and value increase, rather than lower energy bills.

- The operation of the Green Deal framework is too complex. The GD market operating processes are supported by a set of legislative and regulatory frameworks and a number of standard IT systems. It could take some time to go through various processes before the GD plan takes place. The complexity of GD operation has been condemned by consumers and industry bodies. The Government is simplifying the framework to make a more efficient and low-cost operating model.

- Using estimated energy saving to determine GD measures may prevent some buildings and technologies from taking up the GD plan, because they cannot meet the "Golden Rule".

3.3.2.3 Third Party Ownership (TPO)

TPO is a rapidly growing business model trend for distributed renewable energy generation, particularly in the PV market, where commercial companies install, own and operate customer-sited PV systems and lease PV equipment or sell PV electricity to the customers. Third-party PV companies can reduce or eliminate upfront costs, and reduce technology risk and complexity. Third-party PV companies have better positions than individuals to access various financing sources and to obtain policy benefits that reduce the cost of capital. This section looks into the TPO model of PV system used in the US residential market.

The financial model of PV TPO is a cash purchase model, which has two types of contract: solar PPA and solar lease. Under a TPO contract, the homeowner hosts the PV system and the third-party solar company designs, finances, installs, operates and maintains the system in exchange for payments over a long-term contract, typically a 20-year period. The solar energy price is competitive with local retail electricity rates. There are no or very low upfront costs for the homeowners, and they should have very good credit (Solar City, 2011).

Under the solar PPA model, customers purchase electricity based on electricity production, and the electricity rates are locked during the period of contract. The third party solar company may provide O&M. Under the solar lease model, customers make monthly lease payments whether the system operates or not. Lease payments are locked during the contract period. The solar company may or may not provide O&M services. It may include a production guarantee in the lease contract (Speer, 2012).

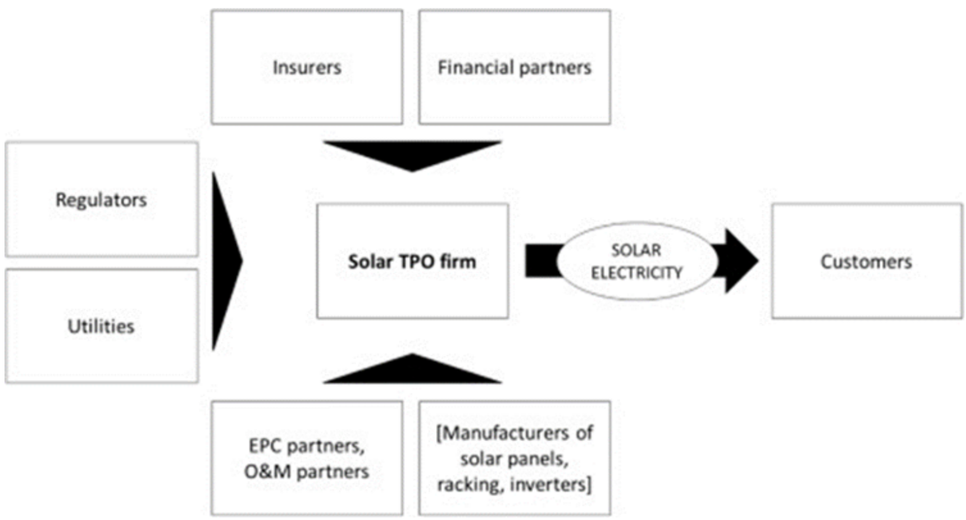
The contracts need long-term commitment, usually up to 20 years. It is transferable upon home sale with buyer qualification. The customers have a buy-out option for the end of the contract.

One important factor for a successful TPO model is that investors can monetize tax benefits. In the US, the tax benefits include federal tax incentives (30% ITC for solar finance companies and accelerated depreciation for tax equity investors). The solar company use a partnership model such as Flip Partnership with tax equity investors (often a large bank or insurance company) to maximize tax benefits for solar investments. The long-term, reliable and bankable local financial incentives in the US also provide reliability and low risk for TPO participants.

It is a key success factor that solar energy can operate and compete with local retail electricity rates. Enabling policies to be in place can provide market conditions for this. In the US, legislation includes the Federal Solar Investment Tax Credit (ITC), Modified Accelerated Cost Recovery System (MACRS) and the Net-metering policy, which make the TPO model a lot more attractive for private investors. The availability of financing sources such as the YieldCo financial structure (Lam, Lam, YU, & YU, 2016) are supporting market conditions for TPO.

The solar TPO participants' relationship is shown in Figure 3.4 below. In the TPO ecosystem, the solar company plays a central role. They can partner with other service suppliers and authorities providing business models from bespoke solutions to one-stop shops for customers (Overholm, 2015).

Figure 3.4: The US solar TPO model stakeholders relationship model (Overholm, 2015)



Lessons learnt from the US solar TPO model (Speer, 2012):

- First of all, to make third-party financing work, it needs favourable margins on investments. In the US, there are several long-term, reliable and bankable government policy incentives, which make this model more attractive to financial institutions.

- In addition, there must be legal or regulatory clarity for solar TPO models (sale and qualify), market conditions and policies that enable solar TPO to operate and compete with retail electricity supply, achieving economies of scale that can bring costs down.

- From the operational aspect, alternative solar contracts work on different investment scale and building types. Using the partnership model, the project can maximize its financial benefits from all available policy incentives.

- Furthermore, Third-Party Ownership benefits include transferring most or all of the up-front cost and transferring maintenance responsibilities to a qualified party.

- However, there is a credibility problem. Lack of trust may be putting off some potential customers.

3.3.2.4 Energy Service Contracting (ESC)

ESC is normally delivered by an ESCO. ESCOs are companies for whom performance-based contracting is a core business activity. Typical ESCO services include developing, designing, de-risking, arranging finances for energy efficiency projects, installing and maintaining the energy efficiency equipment involved, and measuring and verifying energy savings (Yang, 2016). These services are provided via long-term energy service contracts, normally lasting between 5 and 25 years, which fall into two broad categories; energy performance contracts (EPCs) and energy supply contracts (ESCs) (Fawkes, 2007; Sorrell, 2007; Hansen, 2009; Hannon, 2012).

The most common ESCOs contracting type is Energy Performance Contracting (EPC) - an external organisation implements a project to deliver energy efficiency, or a renewable energy project. The approach is based on the transfer of risks from the client to the external organisation, and the payment is based on the performance of the project.

In addition to conventional ESCO services, the evolving ESCO services sometimes include fuel and electricity purchasing. They may also provide or arrange financing (Pätäri & Sinkkonen, 2014). Other types of ESCO include Energy Services Agreements (ESA), in which third party entities negotiate ESAs, arrange/provide capital, develop power plant projects, typically renewable energy, and manage installed equipment for large industrial and commercial projects. The host agrees to pay either a fixed or floating rate for the energy savings received. This structure enables energy efficiency to be treated as a service and an off-balance sheet transaction. Flexible & Scalable Financing involves a single financing package that bundles together multiple sites that have smaller-sized project opportunities. For the purposes of this study, the discussions focus on an ESCO-financed project model, which is an ESA model.

Features of an ESA model:

- In an ESA model, ESCOs finance, or arrange financing (from a third party), for the installation and operation of energy efficiency projects. ESA offers an off-balance sheet financing solution. The customer has no financial risks and only pays a percentage of the actual savings to the ESCO over a specified time period.

- ESCO business is conducted on a product service-based contractual agreement. The ESCO's payment is directly linked to energy produced either in physical or monetary terms.

- ESA enhances the reliability of operations, ensuring long-term reliability and performance of the project equipment.

- ESCOs use sales of energy production to pay for project investment, while lowering client's utility bills and transferring risks from clients to the ESCOs.

- ESCO has two contract models: Shared Savings and Guaranteed Savings.

The conventional ESCO framework is an established framework and has been widely used in low carbon building services, however, it faces low profit level barriers, and the assumed customer's preference for achieving cost savings from the beginning of energy renovation can result in long contract periods tying up the capital. The ESCO model is unattractive in the current business climate, requiring modifications or integration with other services and organisations (Hannon, Foxon, & Gale, 2013; Pätäri & Sinkkonen, 2014; Yik & Lee, 2004).

The ESCO partnership model is an innovative business model that uses a partnership arrangement to help resolve conflicts between a building owner and an ESCO over the operational, financial and legal responsibilities in a building energy performance contract. Yik & Lee (2004) explain that the proposition is made to form a partnership firm, involving the building owner and the ESCO, to assume the performance contractor's role. The proposed partnership arrangement, the key considerations to be taken in forming the firm and the benefits of using the partnership firm for performance contracting are put forward for consideration by building owners and ESCOs.

An Integrated Energy Services Provider (IESP) is another type of modified ESCO model. District-scale developments have a unique opportunity to put in place a dedicated IESP. Such an entity would manage multiple energy-related operations and act as a multipurpose developer, financier, operator and administrator of energy systems, as well as a regulator of building performance requirements. The IESP may be one organization or multiple organizations acting in cooperation but, in any case, the key is to execute multiple functions in concert to achieve performance objectives in the most economical way.

Lessons learnt from the ESCO model:

The objective of the traditional ESCO service is to result in savings for clients by proposing and implementing efficiency measures in existing processes. ESCO has an established and mature business model, which is widely used in energy-saving building projects. Many innovative ESCO business models provide more functional benefits to the clients, such as financing and low carbon energy generation. Based on the existing ESCO framework, the objective of the new ESCO financing model is to realize a LCBT project that client firms would not realize themselves. The new model helps client firms overcome financial and economic barriers by sharing with other parties, while providing low-cost green energy.

3.3.2.5 Summary of key characteristics of each TPI models

A successful third party investment finance structure incentivizes each of the major stakeholders involved, and balances the relative risks of implementing energy efficiency improvements with the resulting energy savings returns and benefits. Each of the three third party financing models examined in this section achieves this balance via different approaches and addresses the major issues to different degrees. A brief summary of each model's major issues with respective solutions is shown in Table 3.3 below.

Table 3.3: Summary of key elements and approach choices for each TPI model (Author's own)

Model Name	Green Deal	TPO	ESCO
Financing models (linked with energy bill)	On-bill financing	Cash purchases	Savings pay
Contract models	GD Plan	PPA Lease	Performance-based Shared savings; Guaranteed savings;
Business models	One stop shop Contracting Partnership	One stop shop EPC Partnership	One stop shop outsourcing of energy management Partnership
Ownership during contract	Host own	Third party investor own	Investor own

	Loans attach to the property (the bill payer)		
Operation tools	Complex	Simple	Mature
Support incentives	Not rely on public subsidy. Government backed bank, model and scheme. Government incentives (ECO, cashback) will help take-up at earlier stage	Investor tax benefits FiT	Tax benefits
Project type	Low cost measures energy efficiency existing building stock in the UK retrofitting homes;	PV, Distributed energy for residential and commercial buildings	Generally high cost measures. Industrial and commercial buildings
CSFs	finance mechanism attaches loans to the property instead of the owner Repayments do not exceed the monthly savings in energy costs; Access to accredited service providers	A long-term contract Ownership transfer Competitive price	Long-term reliability and performance High energy savings
Motivations and barriers	Resident awareness and understanding assessment costs loan interest rates Home improvements Saving money	An individual product or service	Transfer risks from clients to ESCOs Low profit level

Lessons learned:

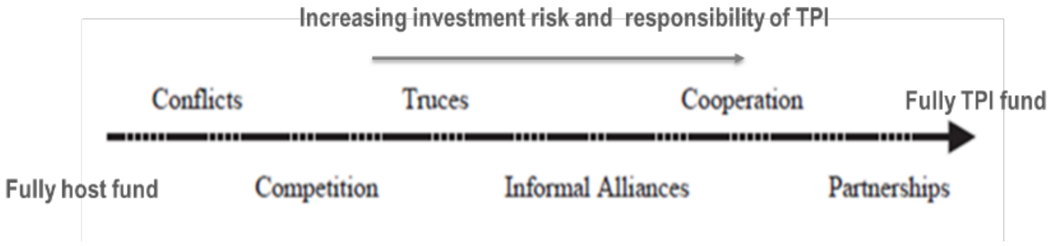
Third party investment approaches aim to help the development of LCBT projects that are considered to be technically and economically feasible, but are not realized by current business approaches due to the lack of required capital, or because the payback period is too long. Various new models, in contrast to BAU approaches, endeavour to help property developers/owners to build low/zero carbon buildings at no or low extra cost, thereby incentivising the adoption of LCBTs. In order to overcome the major barriers and to achieve the objectives, learning from the above existing models, the envisioned TpIP approach should consist of the following features descripted in Table 3.4:

Table 3.4: Identified features from the existing TpIP models to remove barriers (Author's own)

Envisioned TpIP features	Removing barriers
Shifting and balancing costs, risks and responsibilities	High upfront cost
Allocating risks and responsibilities to parties who can be best manage them	High risk and uncertainty
Communicating and dynamically adjusting process	Reducing split interests and risk
All participants gain benefit	Split incentives
Low interest rate loan for investment make desirable return	Low profit level

As the cost, risks and benefits shift from developer/owner, the model also shifts from a developer/owner-centred model to a third party-centred model, as shown in Figure 3.1 and Figure 3.2. Theoretically, as shown in Figure 3.5, the more projects become TPI-led, the fewer risks and responsibilities hosts and users have. However, this also means that the TPI's growing importance results in higher risks and responsibilities.

Figure 3.5: Stakeholders' relationship development (adapted from Walsh, 1995, modified by author)



3.4 Defining TpIP framework classification for this study

This study aims to develop a TpIP framework for LCBTs projects. What should be considered when forming the TpIP framework? What steps should be taken to develop the framework? Currently, LCBTs project are often be implemented on a one-off basis without any specific framework. However, LCBTs adoption is technically complex, involving multiple stakeholders, each with conflicting objectives. TpIP frameworks are important in ensuring that the objectives of the investors, property owners and users are aligned. How can the benefits be best presented when compared with other traditional models in order to eliminate project stakeholders' suspicion and caution?

TpIP can be seen as having multiple roles, such as a financing mechanism, a cooperation model, a business model and a risk reduction model. A TpIP framework should include elements that represent these roles. Therefore, this study classifies the framework into four aspects: financial, legal, operational and risk aspects. For simplification, this thesis refers to the above classification as the FLOR model.

The Oxford English Dictionary defines a framework as "a basic structure underlying a system, concept or text". According to Bult-Spiering & Dewulf (2006, cited by Heurkens, 2012, p 96) a "typology of partnership framework contains prescriptions about the structure of the cooperation and the process of cooperation." The structure is the legal, financial or organisational institution, whereas the process is the actual interaction. Each of these aspects must be undertaken by actors (Heurkens, 2012).

In some research, the researcher will analyse the institutional aspects of a framework as a way to understand the parties' cooperation structures and processes, and its inter-organisational arrangements as a way to understand the attribution of different project necessities to private actors within projects (Heurkens, 2012). The nature of TpIP is very technical and context-specific, and here a TpIP framework consists of a set of procedures, rules and an institutional structure and responsibilities, which will be explained through the FLOR classification in the rest of this thesis.

The choice for one of these models depends on many factors. First, there are types of low carbon buildings characteristics, the existing project situation (complexity and political importance) and the estimated project duration (long or short term). Secondly, the availability of means from actors for the development is of crucial importance for the choice of the TpIP, and these are the availability of space (ownership and accessibility), financial capacity (investment) and organisational capacity (knowledge and personnel). Thirdly, the allowance of sharing or separating and avoiding or accepting risks, revenues, responsibilities and tasks can be crucial factors for the TpIP choice. Hence, these choices also determine the role of host and private investor and the amount of management measures they have in the low carbon building projects. Another interesting aspect of the different cooperation models is the relationship between financial aspects (risks) and organisational aspects (responsibilities). These aspects are of importance for project participants' roles (Heurkens, 2012).

- Defining technologies that are eligible for support. The framework may be most effective for certain kinds of projects within certain technologies
- Financial architecture
- Interaction with incentive policy
- The elements that typically comprise the framework

A TpIP should be a form of cooperation between LCBT hosts and private sector third party investors who, on the basis of their own business objectives, work together towards a joint target, in which both parties accept investment risks on the basis of a predefined distribution of revenues and costs. The next sections explain what needs to be considered to develop a TpIP framework for LCBT projects for this study.

3.4.1 Scope of TpIP Framework

While many elements are broadly replicable in a conceptual TpIP framework, the detailed framework is modelled specifically for one type of LCBT. This research will first set a scope for the TpIP development.

TpIP objectives are multiple and complex and there will not be a "one size fits all" solution. Each TpIP framework must be developed to meet local circumstances and external contexts. Every area has its own particular mix of building stock, economic circumstance, leadership organisations and supply chain opportunities. This study aims to provide a useful framework to support decision makers in the investment in LCBTs that seek to deliver on multiple objectives for the benefit of project stakeholders through a TpIP approach.

In order to develop a workable framework, this study will look at the local context from which the framework is derived. The study's target is the Chinese market. In terms of the local context, it investigates three dimensions: policy, market and resources. The policy dimension includes both limitations and opportunities for China's LCBTs adoption. The market dimension identifies maturity and potentials of TpIP for LCBTs investments. The resources dimension explores the capability, technologies and building conditions. This local context will be explored further in Chapter 6 through a two-stage expert forum.

A TpIP framework should also identify its scope of technologies (energy efficiency measures, low carbon utility, RE generation) and building types (residential, commercial, industrial, infrastructure) for which TpIP is suitable. The framework may be most effective for certain kinds of projects within certain sectors. This study focuses on development of a detailed framework for Chinese BIPV projects. Chapters 6 and 7 of this thesis will describe these issues in more detail.

3.4.2 Consideration for developing TpIP framework

The envisioned TpIP framework will consist of a number of components in its internal structure: financial, legal, operational and risk (FLOR). External support conditions, such as policies, regulations and market support, will also be present along with the framework. We use this classification to guide the development of TpIP framework in this study.

According to the previous literature review of this study, a viable financial model is the most important factor in the success of LCBTs investments. LCBTs come at a cost, and understanding how to correctly and efficiently finance them is key to success. Financing methods including FiT, RHI, ROCs, CfD, PPA, ESCO and EPC can be considered. Finance Mechanisms and incentives offer essential assistance in making LCB projects financially viable. The investigation of the financial component should include: appropriate TpIP financial models, availability of financing means and financial benefits sharing.

The legal framework is the core of TpIP. It includes: adequately identifying local needs, the nature of partnerships and consortia being formed to deliver TpIP activities, parties benefitting directly from TpIP, the private sector acting in a leading role for the market-based approaches and the supporting role of government involvement in the market. The TpIP framework will need to be developed taking into account the legislative and administrative contexts. Therefore, the legal and administrative instruments will be embodied in the TpIP framework, and the legislative and administrative context must be reviewed to ensure that the developed TpIP framework is practical, operational and achievable.

Key partnerships refers to the network of suppliers and partners that make the business model work, such as solar photovoltaic systems, to provide customers with cheap systems and benefits from economies of scale. They could partner with installation companies like local service technicians if they do not want to hire their own staff in this field. Partnership formation can be a valuable entry strategy into new markets (Richter, 2012).

The operational component (business model) comprises the following elements:

- A simplified operational model is key for effectiveness and cost reduction. LCBTs are integral to construction projects, since they offer the most sustainable and cost-effective energy solutions. Good LCBT operation, management skills and management are essential to its success.

- Key resources, i.e. the hardware assets generation / LCBTs to produce electricity and the software services platform/O&M to deliver it to the customers.

- Key activities, i.e. the most important processes, and key partnerships, i.e. cooperation or joint ventures with other companies.

A sound knowledge of risk management is important for success. LCB projects provide huge opportunities when managed effectively. LCBTs can be profitable business opportunities and an excellent long-term investment. However, without effective planning and skills, projects can also be high risk. Risks should be allocated to the party best-placed to:

- Influence the risk factor, where possible.
- Influence the sensitivity of total project value to the risk factor — that is, to anticipate or respond to the risk factor, if it cannot be influenced directly.
- Absorb the risk, where it can neither be influenced nor its impact controlled.

The TPI, in turn, is best-placed to manage construction, and commercial and operating risks. The TPI may pass these risks on to its sub-contractors.

3.5 Summary

This chapter explored investment models for LCBTs adoption on building projects based on market forces. Through review of other existing models, the study shows that financial and economic barriers to LCBTs are the key barriers addressed by current business approaches. This study proposes a TpIP stakeholder model (see Figure 3.2), illustrating that a LCBT contractor undertakes the financing, construction, operation and maintenance of LCBT projects on behalf of collaborating firms and argue why it could be beneficial to stakeholders to adopt it. The TpIP model could help in the development of more LCBT projects.

Chapter 4 Distributed Photovoltaic (DPV) and Building Integrated Photovoltaic (BIPV) Market in China

4.1 Introduction

According to the review of LCBTs (section 2.3.4 in Chapter2) and LCBTs investment in China (see section 2.3.7 in Chapter 2), building integrated photovoltaic (BIPV) electricity generation has the most success potential for TpIP adoption in the current market situation of China. This is because:

1. The Chinese government has recently (since 2013) enhanced its incentives and policies to promote distributed photovoltaic (DPV).

2. DPV systems have good economic performance and higher investment value in most areas in China.

3. The ownership of BIPV system can be separated from the building it is installed.

4. The product (electricity) from BIPV system is measurable and tradable.

Therefore, this research investigates the recent BIPV (including building attached photovoltaic) boom in China. DPV generation refers to smaller solar power generation facilities that are located close to consumers and connected to distribution systems, with access voltage below 35 kilovolts. In this study, BIPV project refers to a DPV system that is integrated into or attached to buildings (it is normally installed on top of building roofs).

This Chapter firstly reviews Chinese solar PV policy (Section 4.2.1), the current BIPV investment models in China (Section 4.2.2) and the economic and financial model of DPV (Section 4.2.3).

4.2 DPV and BIPV background in China

During the course of this research, the PV industry in China has grown rapidly. Due to the dramatic changes in both policy direction and market environment, some obstacles identified in the early stage of the research, such as grid connection, are no longer a significant problem. Meanwhile, new challenges, such as electricity sales reform, have emerged along with the change of technologies and new regulations. Therefore, it is necessary to discuss the changing background of China's DPV and BIPV in relation to this research, in order to better understand the context of BIPV energy market. The following sections explain how the government policy changes helped the PV industry growth in the domestic market (Section 4.2.2) and the current BIPV investment models in China (Section 4.2.3).

4.2.1 China solar PV policy changes

Over the last 5 years, China has rapidly expanded its PV industry. According to the International Energy Agency (IEA, 2017), the country installed more than 34 gigawatts of solar capacity in 2016 - more than double the figure for the US and nearly half of the total added capacity worldwide. China's rapid solar energy growth and booming DPV installation in the past 5 years (2013-2018) were largely effected by national policy changes. Since 2009, the Chinese government has announced policies on PV power generation, hoping to expand the domestic market, ease the impact on the PV industry from global market fluctuations and reduce the excess capacity of the PV industry. China's PV policies reflect the Government's determination to foster the development of DPV. The Government's 13th Five-year Plan (for the period 2016-2020) sets a solar energy target of 110 GW installed capacity, which includes 60GW of DPV installation (see lists of major solar energy policies announced between 2009 and 2014 in Tables E.1 & E.2 in Appendix G).

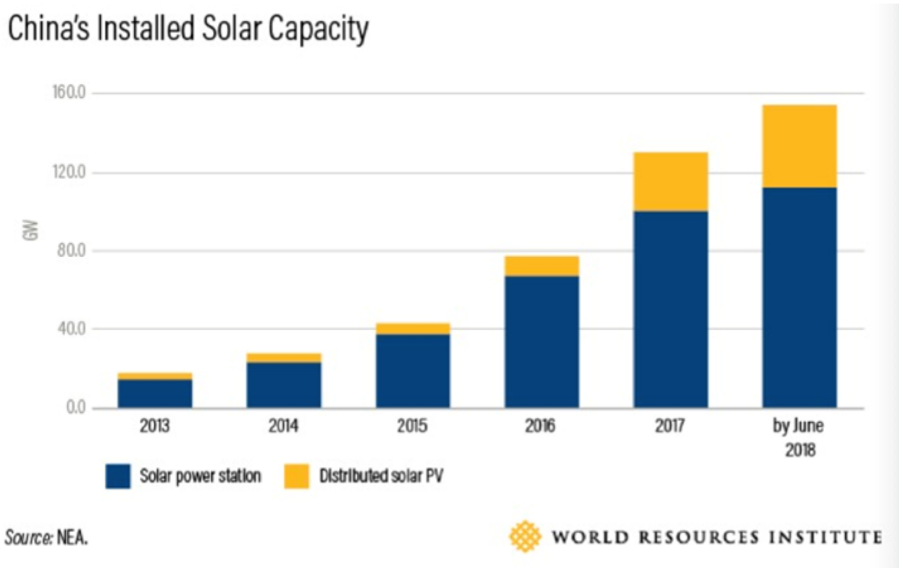
Before 2012, DPV projects were mainly developed under the *Golden Sun Scheme* (above 300kwp) and BIPV Subsidies Scheme (above 50kWp). Both schemes, initiated in 2009, provided PV investors with upfront subsidies prior to the construction of PV electricity generation projects. The schemes and the follow up supportive policies focused on extending the scale of PV power generation in China. Although DPV projects receive incentives from the Government, PV markets were growing slowly especially in the building sector. Developers and building owners were reluctant to adopt the PV system, because of many restrictions, such as grid connection, installing conditions and high cost. The total PV installation capacity between 2009 and 2012 under the two schemes was 6,333.4MW (see Table 4.1 for more details of the approved projects). The Golden Sun scheme, however, proved to be a policy failure. The subsidies for solar installations were based on solar power plant installation capacity, rather than the actual amount of electricity generated from the power plants. As a result, many solar energy project developers purchased cheaper, lower-quality PV panels that produced less energy and some projects were even left un-operated after receiving the subsidies. Moreover, high installation rates in some sparsely-populated regions with abundant land have led to overcapacity and high rates of curtailment (Zou, 2017; Expert E03 interview, 2013). All of these problems resulted in a misaligned and unhealthy PV market, which did not encourage investment in higher-quality and more efficient PV projects.

Table 4.1: Project Statistics of Golden Sun Scheme and BIPV Scheme (2009-2012) Source: CREIA 2014

PV Subsidies Schemes	Number of projects	Installed capacity (MW)
Golden Sun	470	2,977.2
BIPV scheme	444	526.2
Golden Sun and BIPV combined period (2012)	Not available	2,830.0
Total		6,333.4

2013 is the "watershed" for China's PV power installation. It was the starting point for domestic DPV growth. In July 2013 the State Council published a milestone document, *Several Opinions of the State Council on Promoting the Healthy Development of the Photovoltaic Industry,* confirming the Chinese government's determination on further development of the solar power sector. The document encompassed both distributed PV and utility-scale PV, and set a clear target for the PV sector's growth. The Government's determination is a critical factor for encouraging investors to enter its prompting markets (Expert Interview I02, 2014). In September 2013, the National Energy Administration issued *Notice on promoting the healthy development of PV industry by using price leverage* that was regarded as a market game changer for DPV. The document divided the country into three classes of solar energy resource zones, and set the benchmark feed-in tariff for PV electricity generation accordingly. It ensured profit making of distributed solar projects, which attracted inventors' interest. The recent report from WRI (2018) shows that the DPV is growing remarkably faster than large-scale solar power plants over the past 5 years. The share of DPEG in the total accumulated installed solar capacity in China was 27% in 2017, compared with 15% in 2013. See Figure 4.1 below.

Figure 4.1: China's Installed Solar Capacity From 2013 to June 2018 (Source: WRI 2018, based on NEA)



In addition to fostering solar PV growth in the domestic market, the Government also used policy to promote innovation. In 2015, the National Energy Administration launched the "Forerunner" initiative to encourage the use of advanced and high efficiency solar energy products with cost reduction measures. In 2016, developers competed fiercely on bidding for eight large "Forerunner" solar power projects, with a total generating capacity of 5.5 gigawatts. These competitions pushed large reductions on the cost of solar electricity, the lowest winning bid achieved 0.45 yuan (US$ 0.07) per kilowatt hour, which is close to China's benchmark tariff of coal fired power. The "Forerunner" initiative played a significant role in technological improvement and cost reduction. It has helped to bring the cost of solar power down to the point that it can compete with conventional energy without subsidies. The National Energy Administration (2017) predict that PV can achieve parity on the power generation side by 2020, ahead of the estimated 2025. Meanwhile, the Government started to reduce the level of subsidy in 2017 and 2018.

Due to the rapid development of the solar PV market and more efficient PV equipment production, the cost of PV equipment has declined rapidly. The construction cost of DPEG has dropped significantly from 8~9 yuan/W in 2013 to 5~6 yuan/W in 2017, a drop of more than 40%. The cost of electricity has even dropped to 0.5 yuan/kWh. More and more industrial, commercial and home energy consumers are beginning to pay attention to DPEG. This indicates a change in public opinion, and users' low interest can be a barrier for LCBTs investment. The earlier finding in Chapter 3 also found that China's PV industry has been a strong top-down market and investment has depended heavily on government support. There is a need to explore in this study whether the Chinese PV market can also accommodate a bottom-up model and private sector-led investment since the environment has changed.

4.2.2 Current BIPV investment in China

In China, BIPV is also referred to as distributed photovoltaic electricity generation (DPEG), in which electricity is produced on a small scale at the site of buildings. DPEG plants are often installed on the rooftops of buildings. Buildings with a large roof size, such as industrial premises, shopping malls and large office blocks, are targeted sites for BIPV investments. However, investors still face difficulty in raising funds and other complex financing problems, which, combined with a lack of clarity over rooftop ownerships and usage rights, has limited BIPV growth in China.

China's BIPV market is still in an immature stage characterised by a lack of healthy competition. In 2012, most of the developers in the down-stream industry were large-sized state-owned enterprises. In 2013, private enterprises entered the market, which are relatively small in China. A capital barrier prevents new entries into this industry. State-owned property that had enough capital strength still dominated the industry, which were mainly national demonstration projects. In 2014, the Chinese government proposed the reform of the electric power system with the goal of introducing competition to China's electric power market and accelerating the breakup of the grid companies' monopoly. The new electricity trade mechanism proposes that users can directly buy power generated via renewable energy from the suppliers.

Overall, strengthening financial innovation is an effective method of mobilizing financial capital. Therefore, financial innovation tools should be employed to increase domestic enterprise profits and stimulate market applications.

BIPV investments can be classified into three different models: self-funded, joint-funded and third party-funded. The self-funded model is also referred to as the EPC model by some researchers (Zhang, 2016). The EPC model is the conventional BIPV investment method in which the building owner invests and owns the BIPV system, and receives the benefits of the power generation and related subsidies. The EPC is responsible for the application of the preliminary project, the general contracting construction of the project, the implementation of subsidies and grid connection, and the provision of two years of free maintenance. This model has the simplest production relationship and less coordination. Most small-scale commercial BIPV and home BIPV use the EPC model in China (Zhang, 2016).

In the third party-funded model, an Energy Management Contract (EMC) is the most popular model used in current practice in China. An EMC is signed between the building owner and the BIPV system investor. When construction is completed, the two parties start operating in a collaborative way and share profits or savings according to their agreement. The EMC model has two types of agreement – a PPA contract and lease agreement. Under the PPA, the building owner provides the rooftop to the investor for free and receives a solar electricity supply at a preferential price (lower than the market retail price) in return. Under the lease agreement, the building owner leases the PV system from the PV plant investor and makes fixed monthly payments. In general, building owners prefer PPA to the lease model, as the PPA model provides definite savings to the owner and the owner does not need to deal with grid connection for electricity sale issues. In contrast, PV plant investors prefer a lease to a PPA, because it guarantees a fixed and stable income (Zhang, 2016). In the EMC model, the owner enjoys cheap low carbon electricity with zero upfront cost, the third party investor invests, carries out the contracted construction, handles subsidies and the grid connection procedures. The EMC model has a complicated production relationship, a large amount of coordination and a long working period in the early stages. Therefore, this model is mostly used for large-scale industry BIPV projects in China(Zhang, 2016).

Another rapidly growing household BIPV investment model is Photovoltaic Poverty Alleviation (PVPA) projects, initiated by the National Energy Administration (NEA) and Poverty Alleviation Office of China in 2014. The programme utilizes the subsidies and income benefit from PV power generation to alleviate poverty in rural areas (NEA, 2014). It is expected that the projects will deploy at least 10 GW PV and benefit more than two million poor households in total by 2020. The distribution of the PVPA pilot project covered 0.556 million poor households in14 provinces by 2016 (Li, 2018). Although government-led projects are not the focus of this study, there is a huge financing gap for PVPA implementation, which needs novel business models to attract private financial capital. In 2016, NEA issued policies introducing PPP to energy projects to expand the financing source for PVPA projects. The first PPP model PVPA project was developed in Anhui province with a total installation of 67,400 kW in 2015. The project will help 5,000 poor households and 40 villages out of poverty by generating an income of more than 3,000 RMB per year for each household in the next 25 years (Li, 2018). PPP models have played an important role to fill the financing gap for PVPA projects.

In addition, crowdfunding as a type of BIPV investment model has gained increasing attention in China. An example of crowdfunding BIPV project is the 1.5 MW rooftop solar PV power generation on the warehouse in Qianhai, Shenzhen. The crowdfunding initiator promotes the project on the internet platform and the investors choose to participate in the project based on the potential profit. Then the platform company installs and operates the PV system using the start-up funds from crowdfunding. Once the project is completed and starts to generate income from selling electricity to the power grid and obtaining subsidies, the crowdfunding platform will issue dividends to the investors. Crowdfunding is an efficient financial method for third party investment in PV projects. It can not only disperse financial risks and reduce financing costs, but also provide individuals with the opportunity to participate in low carbon investment, as well as increasing public awareness. However, the market still needs to strengthen its supervision mechanism. The failure of Solarbao, a P2P solar energy investment platform in China, shows the market is immature and can have high risks.

Other types of BIPV investment practised in China include the cooperative investment model, in which the building owner jointly invests in the construction of distributed photovoltaic power generation through joint ventures with other investors, and they share benefits. This model is more complicated and is not common in China.

4.2.3 Economy of Distributed Photovoltaic Generation

According to Shao's (2014) analysis of DPVG (Distributed Photovoltaic Generation) in 6 different areas in China, considering the influences of the factors on distributed photovoltaic generation, such as the rate to grid, the electricity price, the supporting policies and the solar resource, the DPVG systems have good economic performance and higher investment value in most areas in China. The IRR (internal rate of return) is above 8% and the stable investment payback period is between 5 to 11 years.

Wen (2018) analysed the economics of a typical 5 kW household Photovoltaic System in Jiangxi Province. The results show that the yearly power generation of a 5 kW household photovoltaic system is 4056.7 kWh, only 79% of the theoretical value. The system has a good economic benefit with the subsidies from the state and Jiangxi Province. The stable investment payback period is less than 8 years and the IRR is 11.2%.

There are four main factors affecting the PV power generation income index: utilization hours, system cost, subsidies and capital costs.

Due to the relatively small scale and high risk of distributed PV projects, state-owned enterprises with low capital costs are not interested in DPV projects. At present, the financing costs of investment companies that are actively invested in construction are rising. The financing costs of these investment companies during the construction period are generally 9-12%, the lease financing costs during the operating period are about 8-12% and the financial costs during the stable period are about 6-8%. With the capital cost raised by 1%, the capital yield will fall by 0.8-1% (Solarbe, 2018).

The returns on investment in BIPV projects will change with the proportion of self-generated power for self-use purposes. **Error! Reference source not found.** illustrates a general revenue model of BIPV under a PPA Model and a Lease Model.

Table 4.2: BIPV Revenue Calculations under PPA Model and Lease Model

Assumptions	
Power generation in a specifies month	(A) kWh
Industrial and commercial power price	(B) CNY /kWh
Proportion of self-generation and self-consumption	(C) %
Government subsidy	(D) CNY /kWh
On-grid benchmark price for desulfurised coal-fired power	(E) CNY 0.4/kWh
Discount rate of sale price for host customer	(F) %
PPA Model	
EMC provider's revenue (①+②+③)	(I) = (G)+(H)+(D)
①Sales of solar power to the host	(G) = (A)*(C)*(B)*(F)
②Sales of excess solar power to the grid	(H) = (A)*(1-(C))*(E)
③Government subsidy	(D) CNY
Host's revenue	(J) = (A)*(C)*(1-(F))*(B)
Lease model	
EMC provider's revenue (lease rental)	(M) CNY
Host's revenue (①+②+③+④)	(N) = (K)*(L)*(D)*(M)
①Electricity bill saved	(K)= (A)*(C)*(B)
②Sales of excess solar electricity to the grid	(L) = (A)*(1-(C))*(E)
③Government subsidy	(D) CNY
④Lease rental	(M) CNY

While the solar EMC model seems attractive to the host customer, it brings about many challenges to the EMC provider who runs greater risks than the EPC company does in the host-owned model. (1) Liquidity risks. (2) Risk of non-performance on the part of host customers. (3) Other risks.

High quality and efficient operation and management (O&M) is the critical factor in ensuring PV power stations function smoothly, which directly determines whether or not the expected return will be produced.

Financing mechanisms for BIPV:

1. Conventional bank loan
2. Local financing platforms
3. Solar PV industry investment fund
4. Lease financing
5. Internet financing (equity crowd-funding, SPI's Solarbao model)

Theoretically, the rate of return on investment in distributed PV power stations is much higher than bank interest rates. As estimated by the Research Institute of the National Energy Administration, the internal rate of return for most distributed PV power generation projects is 8% or above, except for the low tariff users, such as residential homes.

4.3 Chapter Summary

This chapter reviewed the market of DPV and BIPV in China. It revealed that BIPV electricity generation has the most success potential for TpIP adoption in the current market situation of China. China’s rapid solar energy growth and booming DPV installation in recent years were largely effected by national policy changes. The Chinese central government has issued a set of schemes and the follow up supportive policies focused on extending the scale of PV power generation in domestic market. It was predict that PV can achieve parity on the PV energy market ahead of the estimated timeline (NEA, 2017).

The literature also revealed that BIPV markets were growing slowly in the building sector in contrast to the booming PV energy market. Developers and building owners were reluctant to adopt the PV system, because of many restrictions, such as grid connection, installing conditions and extra cost.

There are three different models for BIPV investments: self-funded, joint-funded and third party-funded. Energy Management Contract (EMC), which is a type of third party-funded model, is becoming popular model used in industrial and commercial buildings in China. The study by X. Zhao, Zeng, and Zhao (2015) shows that DPV systems have good economic performance and higher investment value in most areas in China. Typical investment payback period is between 5 to 11 years. However, the returns on investment in BIPV projects are various depending on the proportion of self-consumption and grid upload.

The BIPV EMC provider bears greater risks, such as liquidity risks and non-performance on host and consumers, which hinder the development of BIPV market.

Chapter 5 Research Methodology

5.1 Introduction

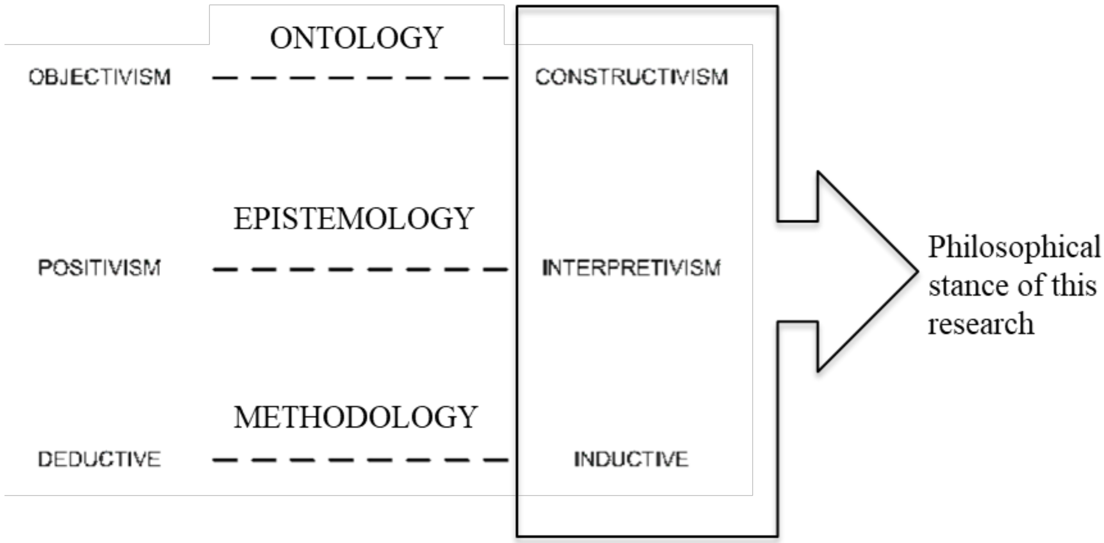
This chapter explains the creation of an appropriate methodology for this research. It presents the approach and methods adopted for this study together with relevant justifications for each of the selections. It also describes the process of different stages of the study, data collection and data analysis. It discusses the techniques used to collect and analyse data.

5.2 Research Design

5.2.1 Research Philosophy

According to Saunders's Research Onion model, research philosophy represents the starting point of the research design (Saunders, Lewis, & Thornhill, 2009). Philosophical stances are one of the factors that influence the design of research studies (Mary & Patrick, 2004). Guba and Lincoln (1994) believe that researchers should consider three fundamental elements: ontology, epistemology and methodology. Each element consists of choices of philosophical stances presenting the research base of assumptions about the nature of reality and the theory of gaining knowledge in the assumed reality. Sutrisna (2009) acknowledges the complexity of the research philosophy classifications and debates, and he asserts that ontology logically precedes epistemology whilst epistemology precedes methodology. He further uses the so-called "continuum" to illustrate the extreme philosophical positions within research methodology and inevitable links between the hierarchy layers. Figure 5.1 shows the two extreme ontological positions are objectivism vs constructivism, and the two extremes of epistemological positions are positivism vs interpretivism (Sutrisna, 2009). Trochim (2006) perceives that more extreme approaches can be delimiting. He argues that only an intermediate philosophical approach allows the researcher to match philosophy, methodology and the research problem. The philosophical stance of a researcher strongly influences the reasoning of his/her research and consequently influences the data required by the research and analysis of the data (Kumar, 2011). The philosophical stance of this research lies in constructivist ontological positions and interpretivist epistemological positions, fitting the nature of this social science-based study. It is against this backdrop that this study is structured as an exploratory study.

Figure 5.1: The extended "continuum" in Research Methodology (Adapted from Sutrisna, 2009, p10)



Based on Saunder's Research Onion model, the second layer of research design is the reasoning of research approach. The two broad methods of reasoning are the deductive and inductive approaches (Saunders et al., 2007). Deductive research entails the development of a conceptual and theoretical structure prior to its testing through empirical observation (Loose, 1993). Inductive research aims to learn about the phenomena in question by applying a "less-structured" methodology to gain richer and deeper information (Glaser, 1978). This research involves inductive reasoning processes, because interpretivism is generally associated with an inductive logical reasoning approach (Sutrisna, 2009). The study areas consist of multi-disciplinary, multi-sector and multi-stakeholder, and there is no existing framework in relation to the purpose of this study within the research scope. Hence, it is better to use an inductive approach in planning and carrying out this research.

5.2.2 Research strategies and methods

5.2.2.1 Research methods

Research methods can be generally grouped into two categories: quantitative and qualitative (Kumar, 2011). Quantitative research is defined as an inquiry into a social or human problem, based on testing a hypothesis or a theory composed of variables, measured by numbers, and analysed by statistical procedures, in order to determine whether the hypothesis or the theory holds true (Creswell, 1994). Quantitative data are, therefore, not abstract, but are hard and reliable; they are measurements of tangible, countable, sensate features of the world (Bouma and Atkinson, 1995). However Grix (2004) argued that some facets of human actions, especially behavioural phenomena, are difficult to capture or 'measure' quantitatively. To study these social phenomena requires another method: a qualitative approach. Qualitative research is 'subjective' in nature. It emphasizes meanings, experiences, description and so on. The information gathered in qualitative research can be classified under two categories of research, namely, exploratory and attitudinal. The differences between quantitative and qualitative research have been compared in Table 5.1.

Table 5.1: Comparison between Quantitative and Qualitative research (Sources: Bryman, 1998, Miles & Huberman, 1994)

Quantitative	Qualitative
Quantitative research classifies features, counts them, and constructs statistical models in an attempt to explain what is observed	A complete, detailed description
Recommended during latter phases of research projects	Recommended during earlier phases of research projects
Researcher knows clearly in advance what he/she is looking for	Researcher may only know roughly in advance what he/she is looking for

All aspects of the study are carefully designed before data is collected	The design emerges as the study unfolds
Research uses tools, such as questionnaires or equipment, to collect numerical data	Researcher is the data gathering instrument
Data is in the form of numbers and statistics	Data is in form of words, pictures or objects
Quantitative data is more efficient, able to test hypotheses, but may miss contextual detail	Qualitative data is more 'rich', time consuming and less able to be generalized
Researchers tend to remain objectively separated from the subject matter	Researchers tend to become subjectively immersed in the subject matter
Evidence hard and reliable	Evidence rich and deep

This research aims to develop a third party investment partnership framework to encourage adoption of low carbon technologies in building projects. Considering the complex and practical characteristics of the research field (i.e. the construction industry), a combination of literature review, an expert forum and case study use is adopted, and a qualitative method is used to achieve the proposed aims and objectives of this research. Case studies are considered a good way to address real-world issues in a meaningful way. Figure 1.1 demonstrates the overall research approach. The initial conceptual framework is mainly built from literature review and the development of a detailed framework is conducted through a case study method. Expert forums will be used to enhance credibility and validity of the research at the different stages of the framework development. The detailed research design is described in the following sections.

5.2.2.2 Expert forum

The expert forum is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas (Dalkey, 1972, p. 15). The expert forum method is designed to obtain the most reliable consensus of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback, and with results of each round being fed into the next round (Linstone and Turoff, 1975; Chan et al., 2001a). It has proven to be a popular and reliable technique for decision making (Okoli and Pawlowski, 2004; Landeta, 2006). It is best suited in fields where there are no adequate historical data for research purposes (Martino, 1973; Skulmoski et al., 2007). Considering the immaturity of the LCBTs investment market in China, expert forum is employed as an appropriate consensus-reaching method for the research topic in this study.

5.2.3 Case Study

Robson (2002) asserts that the case study strategy would be useful if the aim of the study is to gain a rich understanding of the research perspective and the process being endorsed. The use of case studies has been regarded as an important research strategy and yet remains controversial as a research methodology despite its popularity in many fields of study. Various scholars have expressed their pessimistic views (Robson, 2004), while others have regarded the use of case studies as a fully legitimate alternative to experimentation in appropriate circumstances and have considered case studies not as a flawed experimental design but as a fundamentally different research strategy with its own design (Cook and Campbell, 1979). Furthermore, growing criticism of the statistical-experimental paradigm has increased the popularity of the use of case studies in research (Cohen and Manion, 1996). Further, the use of the case study approach has been found to allow investigators to retain the holistic and meaningful characteristics of real-life events (Yin, 2003). In investigating complex situations, such as construction projects, the case study approach has been shown to be appropriate for the capture of complex and rich information (Sutrisna and Barrett, 2007). Thus, in an attempt to capture the informal aspects of construction projects while retaining their complexity and richness, the context in which the phenomena occur captured by the case study has been considered important for the purpose of this study.

Yin (2003b) recommends meeting three conditions to decide upon a research strategy. These are: 1. Type of research questions posed, 2. The extent of control the researcher has over actual behavioural events, and 3. The degree of focus on contemporary issues (pp5). Accordingly, a case study is preferred when the research questions take the form of "how" and "why". Looking at the research questions, it can be noted that they predominantly consist of this type of research question, favouring case study research. For the second condition, in this research, the researcher does not have control over the behaviour of construction project parties and is an observer. Further, the issues being investigated were contemporary and about how the property developers are affected by, respond to and cope with LCBTs currently, satisfying the third condition for selecting case study research.

Proverbs and Gameson (2008) mentioned case study as highly relevant to an industry like construction that consists of different types of businesses and organisations. It was further noted that application of case study research in the construction management domain remains low and that there is significant scope for further application within the domain.

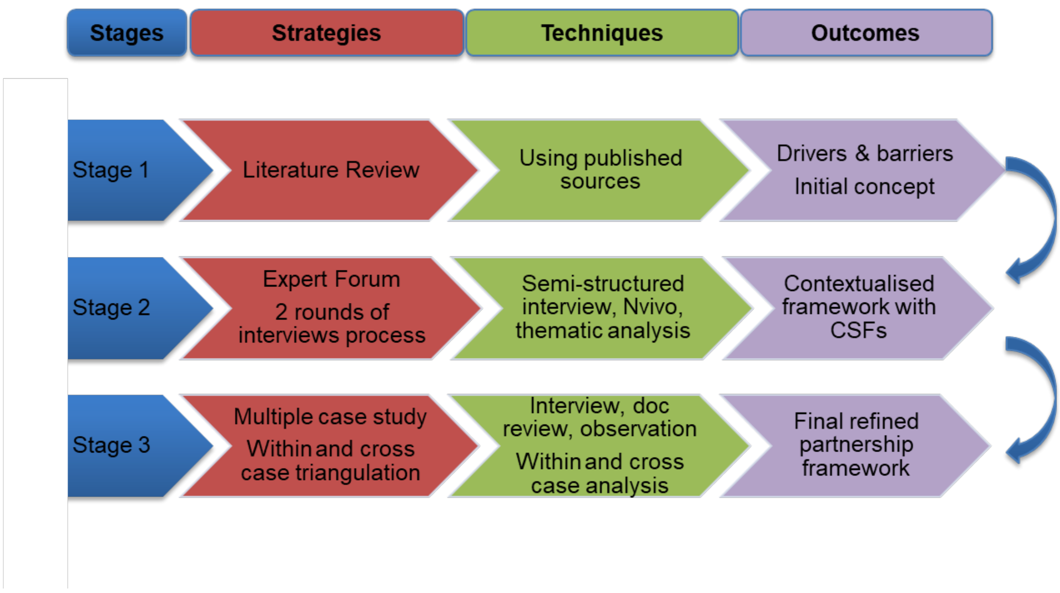
The case study strategy, where in-depth knowledge can be obtained, suits the study of a heterogeneous sector like LCB, where it is often difficult to make strong generalisations across the sector due to significant differences that exist between different LCB projects. Adopting a case study strategy allowed the use of multiple sources of data collection and analysis, allowing the researcher to address the research objectives and answer the research questions satisfactorily (Yin, 2003b; Gerring, 2007). It was sought to use semi-structured interviews and document review as the data collection techniques, in order to better understand the complex network of relationships present within the industry. Fellows (2010) concluded that such methods are gaining recognition within the construction management body of knowledge.

As case study research is subjected to criticism, it is important that validity and reliability of case study research is established by the four tests of construct validity, internal validity, external validity and reliability (Yin, 2003b).

5.2.3 Data collection and analysis Techniques and Procedures

Saunders et al. (2012) assert that the techniques and procedures involve the collection of data and analysis of the data obtained. This study employed both primary and secondary data collection methods. The techniques used for data collection for this study include desktop online searches, semi-structured interviews, on-site observation and document review. Data analysis techniques include thematic analysis, NVivo software and cross-case analysis.

Table 5.2: Research plan



5.3 Research process

5.3.1 Stage1: Building an initial conceptual framework through literature review

This research starts with an embryonic idea of a third party investment partnership (TpIP) for low/zero carbon building development. It is a cost benefit sharing development model between the key project stakeholders. This idea is derived from emerging construction practices in the context of current global low carbon economy and sustainable development (see Chapter 2, research background). This loose concept will be developed into a fully detailed and tested framework through this research.

The first stage is to build an initial conceptual framework. This is mainly done through literature review. The extensive reviewed literature includes sources such as published journals, conference paper, books, reports from government and professional bodies, documents and news from authorities.

Initial concept: The initial concept of a third party investment partnership (TpIP) for low/zero carbon building development is vague and too broad. A funnel approach is used to guide and define the scope of the literature review. Adequate knowledge, understanding in relevant disciplines and theory that are required for the development of TpIP framework are established in this stage.

Identify drivers and barriers: The initial literature review has explored general drivers and barriers for implementing low carbon technologies in construction projects. However, these secondary data are not sufficient for building a TpIP framework, as they are specific in the study. Hence, an expert forum is used to collect tailored data. It is conducted through interviews (qualitative) and is contextualised in the Chinese construction industry. The expert forum process is described in the next section.

Review of other similar models: A review of similar models and best practices is conducted to understand the challenges of different socio-economic conditions feeding in to the framework. It will use secondary data on LCBTs adoption schemes, models, policies, best practice and good initiatives around the world and draw lessons from experience gained through their applications. Success factors (SFs) are identified and categorised in this stage.

5.3.2 Stage 2: Contextualisation of conceptual framework

5.3.2.1 Two-round expert interview

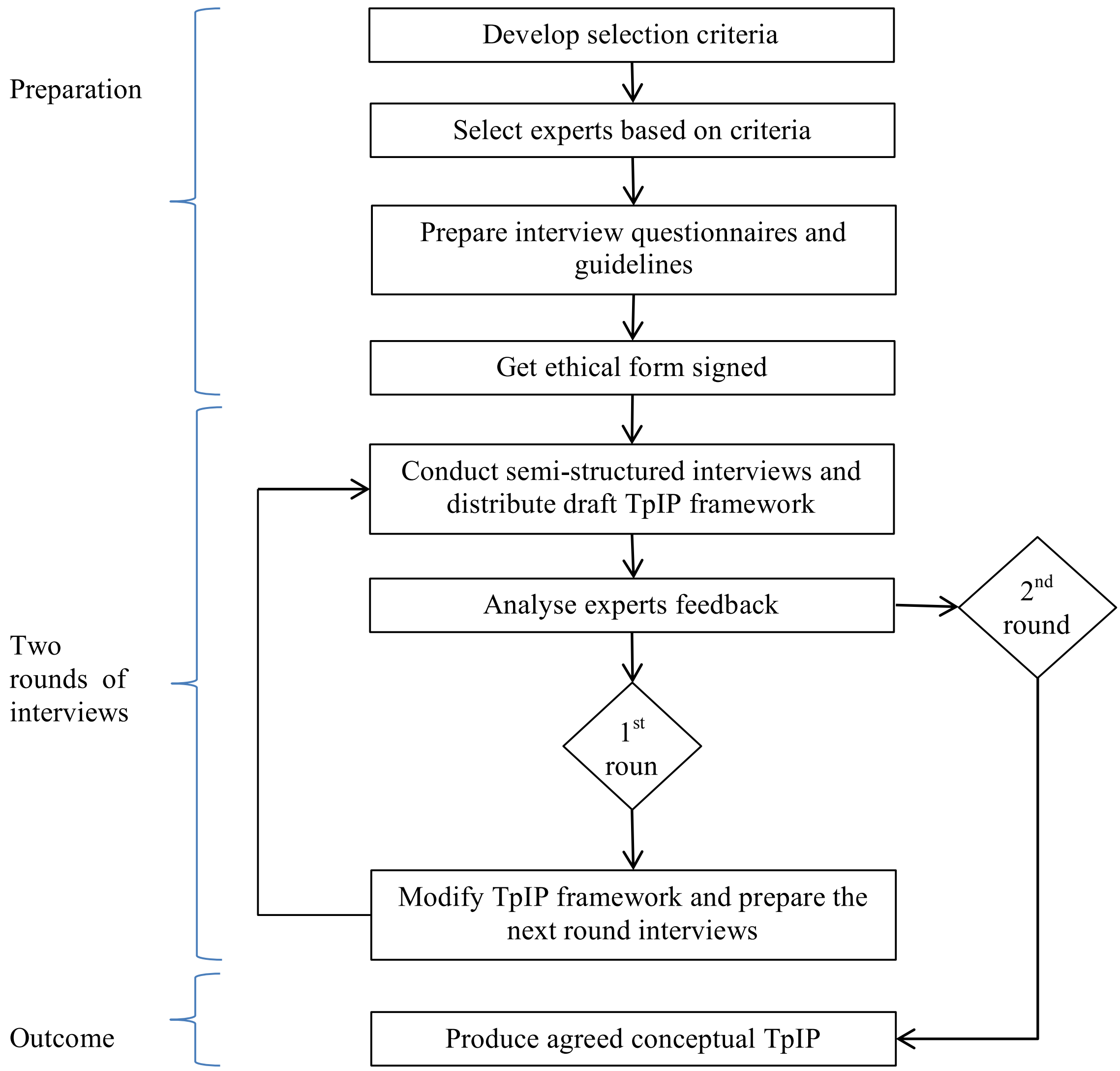
Two-rounds of expert interviews are used to develop a conceptual framework, identifying drivers, barriers and critical success factors (CSFs) and contextualising into the Chinese construction industry.

The expert forum typically involves the selection of suitable experts, development of appropriate questions and analysis of their answers (Cabaniss, 2002). Expert forum studies make use of individuals who have knowledge of the topic being investigated, which McKenna (1994, p.1221) defines as ‘a panel of informed individuals’, hence the title ‘experts’ being applied. According to Ludwig (1997), the majority of expert forum have used between 15-20 respondents. However, with a homogeneous group of experts, good results can be obtained even with a panel as small as 10-15 individuals (Ziglio, 1996). Goodman (1987) asserts that the commitment of participants to complete the expert forum process is often related to their interest and involvement with the question being examined. Therefore, a fine balance must be struck in selecting experts who will be relatively impartial so that the information obtained reflects current knowledge and/or perceptions, yet also have an interest in the research topic. Moreover, if individuals are to be affected directly by the decision to be made, they are more likely to become involved in the study process.

The number and representativeness of participants will affect the potential for ideas as well as the amount of data to be analysed. To provide representative information, some studies have employed over 60 participants (Alexander & Kroposki, 1999) while others have involved as few as 15 participants (Burns, 1998). However, Ziglio (1996) states that with a homogeneous group of experts, good results can be obtained even with a panel as small as 10-15 individuals. Obviously the larger the sample size, the greater the generation of data, which in turn influences the amount of data analysis to be undertaken. This will lead to issues of data handling and potential analysis difficulties, particularly if employing a qualitative first round approach.

The outline procedure of the two rounds of expert forum is shown in Figure 5.2:

Figure 5.2: Procedure of Expert Forum (Author's own)



5.3.2.2 Expert selection criteria

This research comprises two rounds of interviews with 10 experts. All the experts have sufficient LCBTs experience and knowledge (most of them hold senior management positions in relevant organisations). It is believed that with the careful selection of this expert panel, the opinions solicited from them in the interviews will provide reliable results for the research purpose.

One of the most important considerations when carrying out an expert forum is the identification and selection of potential members to constitute the panel of experts (Ludwing, 2001; Stone and Busby, 1996). Dawson and Brucker (2001) state the knowledge and expertise of each panellist must be relevant to questions posed by researchers. In this study, the researcher attempted to identify all the panellists who were knowledgeable or had practical engagement in the LCBTs field. All candidates needed to fulfil the following essential experience and qualifications:

- Advanced university/college degree in building, construction, low carbon technology, finance, property investment and management or other related scientific fields;
- At least ten years' experience in construction, low carbon technology, property finance or building management;
- Leadership or participation in national or international scientific bodies, committees and other expert advisory bodies pertinent to the above disciplines;
- Senior position within his/her organisation or company.

Categorising the experts before identifying them can prevent overlooking any important class of experts. Table 5.3 displays the classifications of expert selection for this study.

Table 5.3: Expert Selection Category (Author's own)

Code	Stakeholders Category	Type of Organisation	Number of Experts
D	Property Developer & Management	Property developer, Building owner, Occupier, management, building service, maintenance	4
I	LCBTs Investor & Installer	EMC, EPC, Contractor, supplier	2
C	Consultant & Researcher	Planner, designer, expert, policy advisory, Universities, research institutes, scientific bodies	3
G	Government authorities	Bureau of construction, green fund, environment and carbon trading	1

Ten experts who met all the selection criteria agreed to attend the interview process after the first contact. A list of the panel members and their types of occupations are shown in Table B.1 in Appendix B, in which experts' names and their organisations are not shown to respect their anonymity. The selected experts represent a wide spectrum of LCBTs stakeholders in China and provide a balanced view for this study. Most of the experts have sufficient experience and expertise in LCBTs projects.

5.3.2.3 Date collection and Analysis: Two Rounds of Interview Process

The first round of interviews collected information in three areas: the expert and his/her company background, China’s current situation and TpIP predictions following an 'interview guide'. The interviews were conducted in Mandarin through individual face-to-face meetings in three cities (Beijing, Shanghai and Shenzhen) in China. The expert forum process begins with an open-ended interview question, the researcher then makes a synthesis of all responses and establishes a draft framework.

Round two: each participant received the draft framework and was asked to review the items provided. As a result of round two, areas of disagreement and agreement were identified. Further check: each panellist received a modified framework according to the feedback in the previous round and was asked to specify the reasons for remaining outside the consensus. The panellists revised their opinions and achieved consensus on the final conceptual framework suitable for the Chinese context.

5.3.3 Stage 3: Refining final TpIP framework – Multi-case studies

As discussed in this chapter, the case study method is the main approach in this research. A multi-case studies method was used to test and evaluate the detailed TpIP framework. It was designed to select three low carbon building projects in China. Three case studies were used with the aim of testing, refining and validating the framework. The conceptual framework was applied to the selected case studies using triangulation methods and cross-case study analysis to further develop a detailed partnership framework. Interviews, documentary analyses and member check will be adopted in the research.

5.3.3.1 Selection of case studies

Three case study projects were selected according to the selection criteria, which are BIPV on industrial and commercial buildings in south China.

Table 5.4: Case studies profile

Code	Building type	Location	LCBTs applications	Contract models	Status
CS1	Manufactural premises	Guangdong province	Rooftop photovoltaic 3.66MW	EMC	2 Phases completed in 2014 in operation
CS2	Supermarket	Guangdong province	Rrooftop photovoltaic 404.80KWp	EMC	Completed in 2011. Ongoing operation
CS3	Multi-users office building	Guangdong province	Rooftop photovoltaic 0.5MW	EMC	Under construction and completed in 2016

5.3.3.2 Data collection

The field work for the case studies took placed between May 2015 and Sep 2016. The data was collected through site visits and observation, document review and semi-structured interviews with key members. A data collection framework was established to guide the conduct of case study activities. The framework consists of a set of topics, from which the researcher needs to collect information and investigate answers in order to conduct a systematic case triangulation and cross-case analysis. The researcher prepared a list of required documents and interview questions in relation to the topics.

5.3.3.3 Data analysis

This study used multi-case studies to develop and refine the TpIP framework. The conceptual framework was applied to the case study project to develop a detailed TpIP framework. This was achieved through deep case study investigation breaking down the concept into framework components, with each component being further investigated to establish patterns and models used, reasons for failure, problems in a real-life project and how it can be improved and problems avoided. Three low carbon building projects were used in order to cross-check data and interpretations. Interviews, documentary analyses and member check were adopted in the research.

5.3.3.4 Case study triangulation

Triangulation has also been viewed as a qualitative research strategy to test validity through the convergence of information from different sources. Method triangulation involves the use of multiple methods of data collection about the same phenomenon (Polit & Beck, 2012). This type of triangulation, frequently used in qualitative studies, may include interviews, observation and field notes. Data source triangulation involves the collection of data from different types of people, including individuals, groups, families and communities, to gain multiple perspectives and validation of data.

The study investigated three BIPV projects using multiple data collection methods including semi-structured interviews with senior executives within each project, secondary and historical data sources and participant observation. The application of triangulation and multiple case studies is discussed in relation to their contribution toward a greater understanding of BIPV practice partnership in the third party investment model, as well as the barriers to the adoption of this model.

Using triangulation and a multiple case study approach provided a wealth of information, which, upon analysis within and across cases, revealed a number of commonalities and some limited diversity. Using this approach maximised the depth of information and increased the transferability of the findings to allow for the development of a conceptual model (Creswell, 1998).

5.4 Research Reliability and Validity

Quantitative research is usually considered to involve a lack of reliability and validity. Triangulation and the expert forum give credibility and conformability to the research.

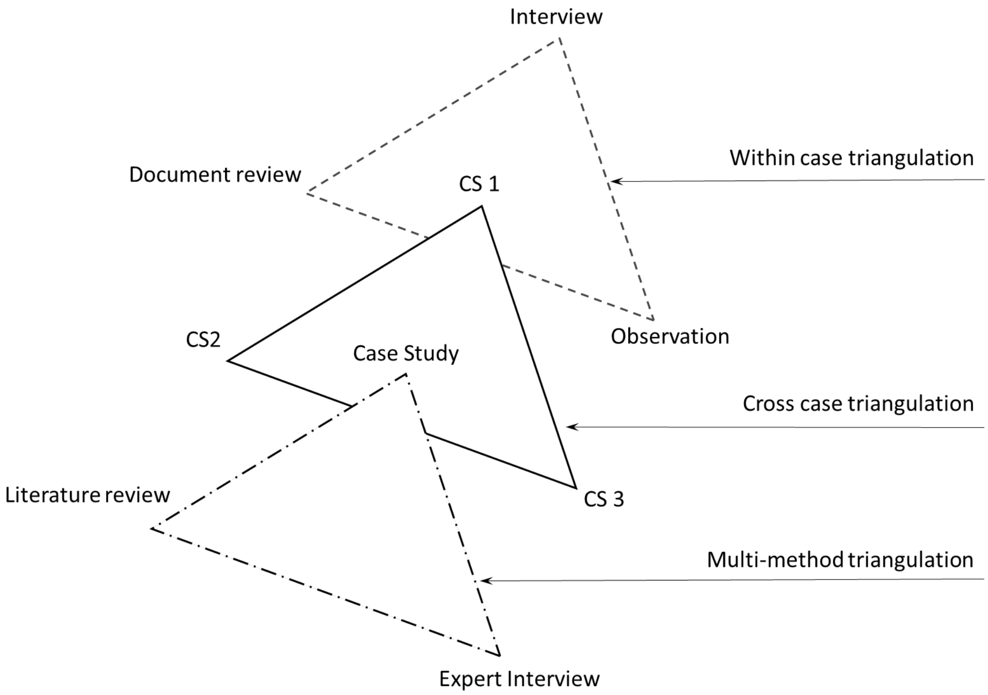
It is important that validity and reliability of case study research is established, by the four tests of construct validity, internal validity, external validity and reliability (Yin, 2009).

Table 5.5: Case study tectics for 4 tests (adopted from Yin, 2003 p33)

Tests	**Definition**	**Case study tactics used in this research**
Construct validity	Correct operational measure for concepts	*Use of multiple sources of evidence* *Have key information review draft*
Internal validity	Establishing a non-spurious causal relationship	*Do explanation building*
External validity	Establishing the domain for generalisation	*Use replication logic in multiple case study*
Reliability	Repeatability of operations of the case study	*Use case study protocol*

This study uses three layers of triangulation, shown in Figure 5.3.3, enhancing the research validity. The first layer is multi-method triangulation: the study adopted a literature review, an expert forum and case studies for the development of TpIP framework. The second layer is within-case triangulation. It uses interview, site observation and document review to test and develop a detailed TpIP framework within a case study. Finally, the third layer is cross-case triangulation: the study used findings in three case studies, then refined and validated the final TpIP framework

Figure 5.3: 3 layers of triangulation (Author's own)



5.5 Chapter Summary

This chapter provides a detailed research methodology and methods employed to deliver the research outcome. It discussed the reasons for the choice of philosophy, research approach (see section 5.2.1), research strategy and methods (see section 5.2.2) among others. This research choose to use qualitative method combining literature review, expert forum and multi-case study approaches for the purpose of this study. It is an exploratory study staring with an embryonic idea of TpIP, then using literature review to explore the concept and elements of TpIP. The study further develops a conceptual TpIP framework contextualised for China though a 2-round expert interview process. For the final stage of framework development, multi case study method is employed to test, develop and refine a final TpIP framework. Three layers of triangulation, including multi-method triangulation, within-case triangulation and cross-case triangulation, embedded in the data collection and data analysis techniques throughout all stages of the framework development ensure the validity and reliability of the study results (see section 5.4).

Chapter 6 Contextualising TpIP Framework through Expert Forum

6.1 Introduction

As explained in the previous methodology chapter, a two-stage expert forum method is used to contextualise the TpIP framework in this study. This chapter explicates the qualitative data collection and data analysis from the expert forum interview, and based on the results, a conceptual TpIP framework for China was developed and validated by the expert panel.

Firstly, Section 6.2 describes the profile of the experts who participated in the expert forum and discusses the interview guidance for the first round of data collection. Section 6.3 explains the findings from the first round of interviews. It explores the current situation and challenges of LCBTs investment in China, identifies barriers, drivers and success factors. Section 6.4 contextualises the TpIP framework by taking account of the findings from the first round of the expert interviews, establishes a conceptual framework that is sent to the expert panel for feedback in the second round of expert forum consultation. Furthermore, Section 6.5 adjusts the conceptual framework according to the experts' feedback from the second round of expert interviews and presents the refined conceptual TpIP framework that was validated by the expert panel through the second round consultation. Finally, Section 6.5 summarises the expert forum process and the key results and findings from the three stages.

6.2 Expert interviews

6.2.1 Expert Panel

In order to provide a balanced and representative view for predictions of the TpIP framework, ten experts who met the selection criteria set for this study were selected to participate in the expert forum process (see section 5.4.2).

All participants have postgraduate degrees in related fields. Five participants have Masters degrees and five participants hold PhDs. All participants have at least ten years' experience with multiple skills from design, finance, building, operation and policy in the low carbon building industry. Seven participants have 10-19 years' experience, two participants have worked for 20-29 years and one participant has over 30 years' experience in construction. All participants occupy senior positions within their organisation/company. Three of them are company directors and seven participants are division directors.

Participants were chosen from a variety of backgrounds representing a wide spectrum of LCBTs stakeholders in China, including property development and management (n=4), low carbon building consulting and research (n=3), low carbon building technology investment, finance and/or installation (n=2), government authority in carbon policy and trading (n=1). More information about participating experts can be found in Table B.1 Expert Profile in Appendix B.

6.2.2 Interview questions

In the first round interview, the researcher aimed to collect information in three areas: the expert and his/her company background, China's current situation and TpIP predictions. By investigating these areas, the researcher can gain deep understanding of the practical situation of LCBTs development in China and gain expert opinions and predictions on the third party partnership approach.

Semi-structured interviews give interviewees the freedom to express their views in their own terms. It can provide reliable, comparable qualitative data. The interviewer often develops and follows an 'interview guide', which is a list of questions and topics that need to be covered during the conversation (Bernard, 1988).

All interviews were conducted in Chinese. Interview guidance for conducting the first round of expert interview was prepared in both English and Chinese. The topics and questions in the interview guidance were translated into Chinese (see Interview Guidance for both English and Chinese version in attached Appendix C). The guidance consists of guiding questions under four topic sections. During the interviews, more questions were raised depending on the responses from individual participants.

6.2.3 Language issue and interview data records

There was a language issue in this research. The expert forum was conducted in China, all participants were Chinese speakers and all interviews and correspondences needed to use Chinese. In order to make sure all participants understood the purpose of this research and the process of the expert forum, the researcher prepared an information pack in both English and Chinese, which was sent to all participants before interviews took place. The information pack includes research introduction, research participant consent form and research information sheet. All documents were presented in bilingual form (Chinese and English). The document pack is attached as Appendix D in this thesis.

The first round of interviews was conducted through individual face to face meetings in three cities (Beijing, Shanghai and Shenzhen) in China. Before the participants took part in their interviews, they read the research information and understood the purpose of the research. All participants signed Consent Forms prior to their interviews. All interviews were audio recorded and key notes were taken during the interviews. The digital audio records were transcribed verbatim in the original language (Chinese) used in the interviews. All the interview transcripts were then translated into English by the researcher. Each set of interview data is formatted into a two-column table, Chinese transcripts on the left side and the corresponding English translation on the right hand see interview data sample in attached Appendix E). All interview data were uploaded into NVivo software for data analysis. To make sure the cross-language data in different forms were consistent, the author conducted the bilingual information pack preparation, interviews, note taking, transcription, translation and coding process all by herself. The researcher is a native Chinese speaker, and she used this method to ensure the maximum accuracy and consistency of using translated data in the research process. During the coding process on Nvivo, the researcher analysed each line of the English text in the right column, at the same time checking the Chinese text in the left column within one display panel. Although the coding process is presented in English, it is easy to trace back to the original sources. It was time consuming for the first one to determine how to arrange the cross-language data in NVivo. No example of a similar situation has been found in other research. The researcher tried several ways, and finally set a template, which was easy to use. This template saved times for processing the rest of the interviews. Table E.1 in Appendix E gives a snapshot view of how the interview data and coding analysis are presented in NVivo. On one coding panel, the Chinese transcript of an interviewee's answer to one question is displayed in the left column, the English translation is presented in the column right next to it, the coding notes for each line can be found in the right side of the coding panel.

6.3 Findings from the first round of interviews of the expert forum

6.3.1 Participants and their organisations' background

Through conversations with each participant in the background section, the researcher revealed that developer and consultant participants are familiar with low carbon building technologies and regulations. Participants from government and investors are more knowledgeable about policies and finance. All participants have their own professional background and work in cross-sector environments in various areas of low carbon building. One participant in academia works as both industrial consultant and academic researcher. Participants in the construction industry also worked in research. The participants in the consultant category have experience mainly in system design, technologies and performance. The participants from the developer and investor categories have experience in using pioneering investment approach on LCBTs on their building projects. One investment company is dedicated to renewable energy investment in both stand-alone and building-integrated renewable energy generation.

Overall, all participants demonstrated strong professional knowledge in their own field and cross-sector collaboration. They formed a balanced multi-disciplinary expert panel for this study. Seven participants have rich practical experience in the full life cycle of LCBTs projects. They are key decision makers and have led their organisations or companies to develop pioneering low carbon projects since low carbon building was introduced in China.

6.3.2 Identifying drivers for LCBTs adoption in China

Drivers were identified through a qualitative thematic coding method on interview transcripts and meeting memos. There are 26 drivers coded that are grouped into 6 categories, see Table 6.1 below.

Table 6.1: Drivers identified from expert forum (Author's own)

Driver Categories	Coding reference
Driver 1 Save money for bill payer	Save money for user (C02, D01 & D02) Reduce operational cost for self-owned commercial building (C01 & D03)
Driver 2 Higher sale value for property developers	Higher sale value for developer (C02 & D03) Reduce long-term operational cost (D01) Sell better and higher price for residential building (D03) Marketing (G01, D03 & D04) Selling points (G01, D02 & D04)
Driver 3 Regulatory compliance	Regulatory compliance (C01, C02, C03) Compulsory (G01)
Driver 4 Government guidance and incentives	Government incentives (C01 & C02) More effective policy in DG Solar (C02 & D03) Government clear attitude towards low carbon development (C02, D01 & D03) Government guidance (G01)
Driver 5 Self requirement	Alternatives to meet required function in addition to low carbon (C02) CSR (D01, I01 & I02)) Company strategy (I02 & D01) Individual interests (I02) Cooperation targets/direction (I02) Building evolution trend (I02) To be pioneer (I02)

Driver 6 - Investment opportunity	Financially viable (C02) Market demand (D01) PM2.5 air pollution (D01) Water safety (D01) Building acoustics (D01) Operation demand (D01 & D03)

Participants (C02, C03 & D01) pointed out that drivers should be seen from different points of views, for example, investment opportunity may be a driver for a supplier or financer, but it is not a driver for a property developer.

All participants indicated that financial benefit is one of the major drivers for all parties involved in LCBTs projects. However, they also stated that low carbon building projects are mostly taken as a way to meet green building standards instead of profitable investments. In addition, LCBTs' benefits are not always obvious and it is possible to make a financial loss (I01, D01). Even when driven by the investment benefit, investors mainly look for short-term economic returns, which can become a barrier when the return period is long term. This point will be discussed in the next section.

The participants all suggested that regulatory compliance, government guidance and incentives are major drivers for LCBTs adoption in China. The literature review (Chapter 2, section 2.3.5) shows that government intervention has been seen as the biggest driver for the low carbon building market, and this is particularly the case in China. China's construction industry is a top-down market, where the Government has a very strong influence on the private sector.

With increasing environmental awareness, some corporations and individuals are starting to require carbon reduction in their operations. Self-requirement is identified as a driver, and participants (C01, I01, C02, C03, D01 & I02) also explained that this is not a strong driver in China. Participant I01 said, "People talk more, act less".

Overall, the external drivers (Drivers 3 & 4) are major motivations in the current Chinese market. The internal driver (Driver 5) does not have much effect on the private sector. Market drivers (Drivers 1, 2 & 6) are only effective among a small number of pioneer companies and individuals. More time is needed for these to demonstrate their effectiveness before the market accepts them.

6.3.3 Identifying barriers to LCBTs adoption in China

Barriers are identified through a qualitative thematic coding method analysing the participants' responses to the interview guidance question 2.4 in the first round of the expert forum. 73 sub-codes are identified as barriers from interview transcripts and memos. These sub-codes are further grouped into 16 coding titles. See below Figure 6.1 abstracted from NVivo screen.

Figure 6.1: Barriers coding process shown in NVivo (Author's own)

Barriers	5	73
Skills and knowledge barriers	5	13
Uncertainty of political will	4	9
Weak market demand	4	8
Lack of market support	3	6
High capital cost	1	5
Low profitability	1	5
Conflict interests between stakeholders	2	4
Complicated ownership structures of multi-family buildings	1	4
Extra costs	2	3
Lack of financing sources	3	3
Low carbon benefit not obvious	2	3
State-owned companies dominate market	2	3
High financial risk	2	2
Lagging laws and regulations	1	2
Lack of market integrity	2	2
Long payback period	1	1

The top three barriers indicated by all participants in the interviews are lack of skill and knowledge, uncertainty of political will and lack of market demand. These are followed by lack of market support, lack of financing sources, conflicts of interests between stakeholders, extra costs, benefits not being obvious, high financial risks and lack of market integrity, mentioned by more than half of participants.

The least important barriers are high capital cost, low profitability, complicated ownership structure, lagging laws and regulations, and long payback period. These participants were from a financial background and/or had experience in low carbon investment and financing, so these barriers are equally essential, even though they were indicated by less than half of the expert panel.

The expert panel indicated that different parties in low carbon buildings projects face different barriers when adopting LCBTs. According to the response from research participants, Table 6.3 below shows the key barriers identified for different parties. i.e. Property developer, third party investor and owner/tenant.

Table 6.2: Key barriers identified for different parties (Author's own)

Property Developer	Third Party Investor	Owner/Tenant
Extra cost Split incentives Lack of skill and knowledge Lack of market integrity Lack of market acceptance Weak market demand Buyers do not care about low carbon building Lack of interest and awareness Lack of market support Uncertainty of political will	High capital cost Lack of financing sources Low profitability Complicated ownership structures of multi-family buildings High financial risk Lagging laws and regulations Weak market demand Conflict interests between stakeholders State-owned company dominates market	Lack of access to financing Lack of market integrity Long payback period Low carbon benefit not obvious Lack of interest and awareness

Experts described with examples and details the obstacles that they or their companies faced in practice. This information provides a deep understanding of the barriers in China's market. The barriers in the above list may have subtly different meaning in a

Chinese context compared with the term barriers identified in the literature review (see Chapter 2, sub-section 2.3.5). For example, both upfront cost and split incentives are the major barriers in the literature review and this expert forum, but they are slightly different between China and western countries.

Upfront cost

The extra cost of China's green building is relatively small compared to the property sale price. According to MOHUD's survey, one-star green buildings cost the same as standard Chinese buildings. Three-star green buildings cost an extra 11-157RMB/m^2 (£1-16/m^2), which is acceptable in first-tier cities. The benefit from the investment is not obvious, a real barrier that discourages adoption.

Split-incentive

In China, the split-incentive barrier is between developer and buyer, whereas, it is between landlord and tenant in the UK. If low carbon features do not help to speed or increase the value of property, there is no motivation for developers to invest in them.

No commitment on government incentives

In China's top-down market, government policy influences private firms' willingness to implement LCBTs. Although the green building incentive policy has been announced, there is a lack of dedicated funds to deliver the incentives, which makes property developers confused about the government's commitment to low carbon, weakening their enthusiasm towards low carbon building.

For example, participants stated that: "*The money (incentives) has never been in place*" (D01). "*The government's award is giving green titles not money*" (D02). "*State-owned companies monopolise the market and get grants, private companies do not have access to government green fund*" (C02). Lack of 'political will' is another barrier for property developers.

Lack of low cast financing

The participants emphasised barriers of high financing costs and lack of financing sources. Moreover, they could not access low cost capital. Long payback and longer-term leases are less attractive for both companies and investors who require a short return on investment. Low carbon equipment with larger capital investments are often not considered by property developers with strict ROI requirements.

Outdated government administrative systems

Interviews found that some outdated legal administrative systems prevent low carbon building innovations and adoptions, and the lack of financial incentives and the mismatching of market mechanisms hamper the promotion of building energy efficiency. Other barriers include inappropriate policy, no access to information about special funds and lack of financial support.

Lack of knowledge

Chinese consumers rarely invest in low carbon building products. The main reasons can be due to their lack of knowledge about the benefits and co-benefits of low carbon buildings, the lack of capital to buy low carbon equipment and the high cost of alternative technologies. The lack of market transparency is another barrier which hinders investment in LCBTs.

Lack of clients' acceptance

Public acceptance of low carbon building is low. Most Chinese people believe that the government should play a key role in carbon reduction, instead of linking the action to their own behaviour.

Insufficient risk/ return value proposition compared to carbon-intensive options and lack of availability of long-term finance prevents private investors from engaging in LCBTs investments with long-term return.

Lack of market support

There is a lack of market for low carbon building service business opportunity, along with a lack of an enabling technical, business and knowledge environment and of adequate supportive policies to compensate for higher prices associated with LCBTs, especially renewable energies. The low cost and low risk LCBTs have less need for third party investment, as the owners normally build the project themselves. There is a trust issue and hosts may be unwilling to share process information with new partners.

Participants also criticised the lack of technological know-how. One participant, a property developer, said that an acceptable payback period for extra investments in green building technology is usually in the order of 2 to 3 years, but for his organisation, up to 10 years can be acceptable if the return is very stable, predictable and low risk. When investment needs are small, risk is reduced and chances are higher for collaborating firms to build the project themselves.

The third party investment motivation relies on market forces, whereas, in China, LCBTs participants are usually motivated by environmental legislation.

6.3.4 Current situation on low carbon building projects in China

Participants explained the characteristics of China's low carbon building market and the investment models used in China. Findings about the characteristics of China's low carbon building market are as follows:

Complicated ownership structures of buildings

All participants think that LCBTs adoption is particularly difficult for residential buildings in China. This is due to a number of factors: residential buildings in urban areas are normally multi-family blocks, ownership and usage rights of shared building structure parts or communal areas are complicated and sometimes are not clearly defined; consent is required from various stakeholders for installation and operation, which is sometimes impossible to achieve. Because of these barriers, investors rarely consider installing LCBTs in residential buildings in China. Besides, the residential energy rate is low, making the savings less attractive for homeowners and investors.

Short lifespan of buildings and companies

Even for commercial and industrial buildings that are viable for LCBTs investment in theory, there are still barriers for adopting LCBTs in practice, such as the average company's lifespan and the average industrial building lifespan being short in China, which increases the risk for the LCBTs investments that rely on long payback periods for investment return. In addition, frequent changing of tenants is also a barrier. It is often very hard to negotiate contracts with commercial clients. Transaction costs can be high if each deal is heavily negotiated. For retrofit buildings, there could be an extra cost for reinforcement of building structures and sometimes the installation may interrupt clients' operation and production. All these are hurdles for LCBTs investors and make suitable buildings difficult to find.

Conflicts between legal framework and policy

Law and regulations are sometimes not updated to the current policy or market direction. The Chinese Government encourages the private sector to invest in distributed renewable energy and sell electricity to consumers, such as building integrated PV power generation. However, the current electricity retail market is regulated for state monopoly. The private sector does not have the right to sell electricity in the market. This conflicts with government policy.

Some old building standards are inappropriate for the local climate. For instance, in the Yangtze delta, where heating has already been supplied in the winter, building standards still do not have the corresponding heating design standards, which impairs investment in building energy efficiency.

Enforcement is difficult to deliver due to the weak legal system. Supervision and monitoring mechanisms are very weak, mainly due to the extremely complex construction process and deficiency of regulatory capacity.

Current investment models in China

Participants identified some investment models currently practised in China, including self-investment, ESCO financing and Build-Lease-Transfer (BLT). The most common investment model is self-investment. For new buildings, LCBTs are included as part of green building features from the building design stage. Property developers invest and install LCBTs using conventional construction procedures. Most LCBTs adopted by developers are replacements of traditional building components or construction materials. Normally, developers choose the most cost-efficient low carbon products to meet the minimum requirement of green building standards. The extra cost of those LCBTs are not a burden for developers. However, if the developer applies the LCBTs on a large scale to their building projects, the total extra cost will hugely increase. One participant from a property development company revealed that their company committed to building 1- 2 million square metres of 3-star standard green buildings per year, which costs an additional 100 million yuan every year, that means the company is making 100 million yuan less profit than they would have been without using these LCBTs. However, when this total amount is allocated to single projects, it becomes affordable and the extra cost is not a major concern for the project manager (D02 interview, 2015).

For LCBTs with high upfront costs and long return periods, such as mechanical and electrical equipment for commercial building projects, some projects are trying to use a third party investment and management model, but these attempts have not proved to be successful.

Some building projects use an Energy Management Contract (EMC) and an Energy Performance Contract (EPC) for ESCOs financing and installing energy provision, such as PV electricity. But these projects are capital intensive and lack financing sources, which prevents the business growth of ESCOs.

6.3.5 Identifying success factors for TpIP low carbon building projects in China

The participants indicated 12 key issues of importance for LCBTs investment in the Chinese market. The first is the Government's commitments, which was perceived to be the market's "weather vane". The second influential factor is market maturity. A supporting legal framework, industrial standards, qualified suppliers, reliable products are the enabling conditions. The third influential factor is that it has to be attractive and interesting to users. Further issues and their explanations are summarised in Table 6.3 on the next page.

Table 6.3: Key factors identified for LCBTs adoption in China (Author's Own)

No	Key issues	Suggestions
1	Suitable technologies	Generate revenue; Separate Asset from building; Be mature and reliable; Transferable ownership; Competitive, cheaper than conventional technology; e.g. Energy efficient electrical equipment and renewable energy generation
2	Suitable building types	Large-size commercial building blocks, manufactories, public buildings and other types of buildings with high energy consumption are suitable building types. The equipment location site/space should have explicit ownership and usage rights. Multi-family residential buildings are not viable for TpIP project.
3	Third party professional capability requirement	Third party investors should have high professional capability in investment and operation of the adopted technology, be familiar with the industrial procedures and access, ensuring smooth development and operation, thus lowering risk to the host party and lowering operational cost.
4	Independent authentication system	LCBTs adopters are confused when selecting the right company. The emerging market lacks integrity. There is a need for a public information platform for checking companies' creditability, listing qualified companies and blacklisting fraudulent companies reducing business risk.
5	Legal framework	Contract may vary depending on the type of project. It could be either a bilateral or multilateral partnership agreement among developers, third party investors, building owners, property management company and occupier. Services include design and installation, O&Mof systems and project financing.
6	Financing mechanism	Government should create a green financing mechanism providing discounted rate loan to project financing. This is an important financial factor for the success of business.
7	Insurance participating	This factor is to reduce the risks for participating parties in the event of uncontrollable situations.
8	Risk allocation	The risk will be allocated to the party who is able to manage it best.
9	Equity of partnership	Ensure fair share of cost, benefit and risk between all parties.
10	Standardised operational process	Replicable, time efficient, low cost operation of business.
11	Trouble free to user	Making it easy for users will encourage adoption. No conflict with users' interests, building functions, no disturbing business production, no opposition from neighbours or public.
12	Ensure market demand	Through project design, legal contract to ensure stable demand and revenue.

According to the above issues collected from the first round of expert interviews, the study further refined and grouped all factors into a five aspect framework that represents financial, legal, operational, risk and external enabling conditions. The results abstracted from NVivo are attached in Appendix F, which demonstrates the coding process of expert panel interviews. Table 6.4 shows the summarised results.

Table 6.4: Expert Forum identified five aspects for CSFs for LCBTs Adoption

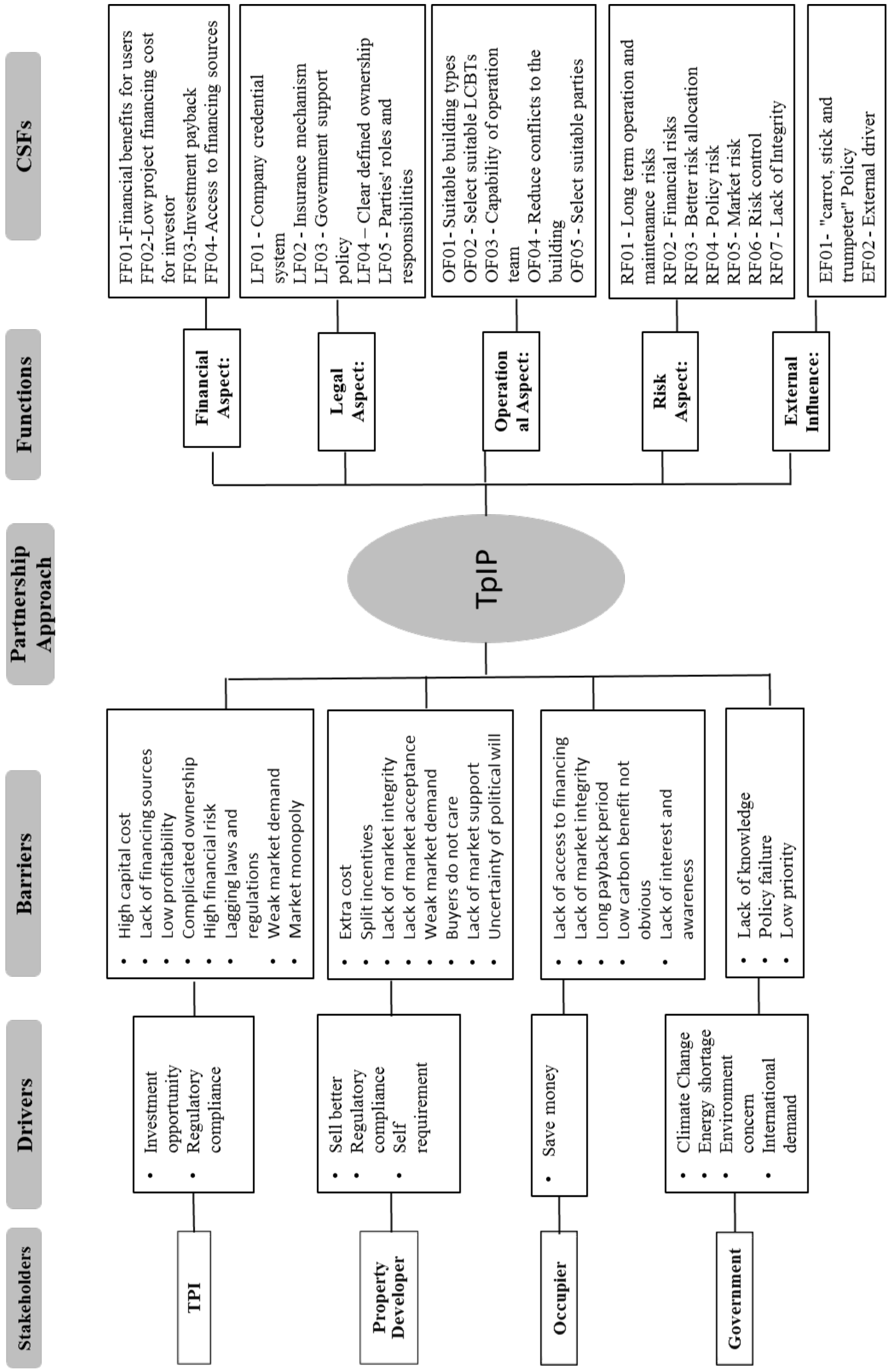
Aspects	CSFs are identified
Financial	FF01-Financial benefits for users FF02-Low project financing cost for investors FF03-Investment payback FF04-Access to financing sources
Legal	LF01 - Company credential system LF02 - Insurance mechanism LF03 - Government support policy LF04 – Clearly defined ownership LF05 - Parties' roles and responsibilities
Operational	OF01 - Suitable building types OF02 - Select suitable LCBTs OF03 - Capability of operation team OF04 - Reduce conflicts to the building OF05 - Select suitable parties
Risk	RF01 - Long term operation and maintenance risks RF02 - Financial risks RF03 - Better risk allocation RF04 - Policy risk RF05 - Market risk RF06 - Risk control RF07 - Lack of integrity
External Enabling Conditions	EF01 - “carrot, stick and trumpeter" Policy EF02 – Healthy market EF03 – Mandatory regulations EF04 – Reform monopoly market EF05 – Inspection in place

6.3.5 Conclusions

This section analyses drivers, barriers and success factors for LCBTs adoption in urban development in China, in relation to the research subject private sector-led TpIP low carbon building projects. It also explores the main characteristics of China's low carbon building industry and the current practical models applied in China. Furthermore, the study categorises the critical success factors into five aspects, which are finance, legal, operation, risk and external enabling conditions (FLORE). The findings also reveal that LCBTs investment is an immature market with a wide variety in market focus and that project developers often take the lead in development projects in various manners.

These findings are summarised and presented in Figure 6.2 below, which is then used to propose a draft conceptual TpIP framework for acquiring feedback from the expert panel.

Figure 6.2: Conceptual TpIP Framework from first round Expert Forum (Author's own)

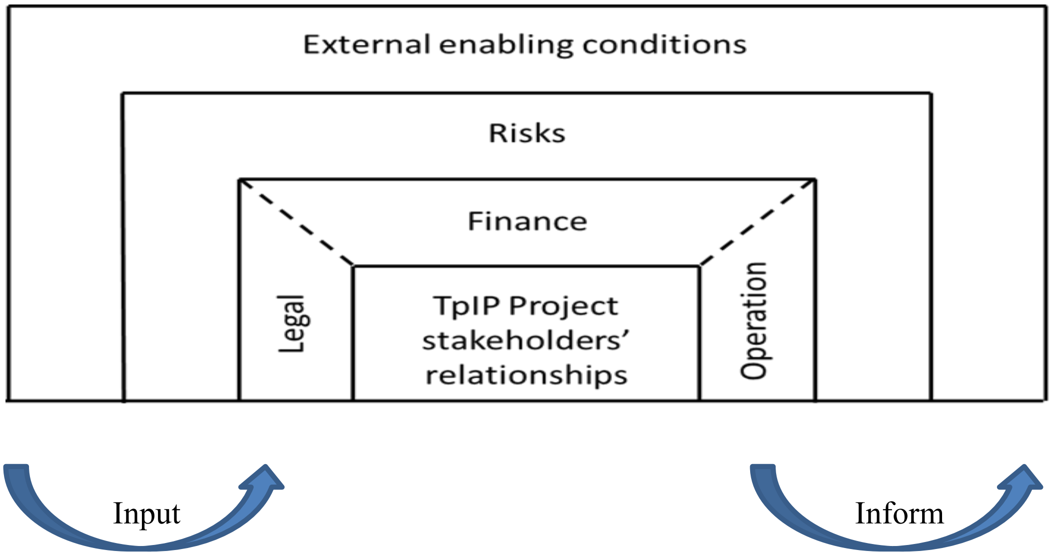


In the next section, the research uses the outcomes drawn from the above analysis, combined with the conceptual framework from literature review, to conduct the second round of the expert forum, getting experts' opinions and achieving consensus on the conceptual framework suitable for a Chinese context.

6.4 Developing FLORE model for TpIP framework

The objective of this section is to establish a conceptual TpIP framework encapsulating CSFs, drivers and barriers identified from previous sections, and representing financial, legal, operational, risk and external enabling parameters that are appropriate in a Chinese context. The findings from the expert forum shows that China's low carbon development is a top-down industry. Government influence is the main driving factor for low carbon investment. Allowing private investors to access the state-owned monopoly market and preferential policies is the premise of private sector-led investments. The Government needs to take strong action to show its willingness to reform the industry. Recognising the importance of this fact, the study adds external enabling conditions to the TpIP framework aspect classifications. The researcher proposes a five-dimension FLORE conceptual model according to the above analysis described in Section 6.3 and the lessons learnt from similar models used elsewhere. As shown in Figure 6.3 below, the FLORE framework is used to analyse TpIP stakeholder relationships in order to provide a clear structure for the development of a TpIP framework.

Figure 6.3: FLORE model for the development of TpIP Framework (Author's own)



In the second round of expert interviews, the expert panel was asked to give feedback on the results from the first round, which includes the stakeholders structure for a TpIP project and the CSFs identified within the FLORE framework. The following section explains the feedback from the second round of expert forum.

6.4.1 Stakeholders structure

In order to illustrate comprehensive TpIP stakeholder relationships and network structures, the researcher connected with all aforementioned stakeholders who participated in a TpIP project in the first round of the expert forum, then grouped them into actor categories according to their roles and presented a draft stakeholders structure in the second round of the expert forum for feedback. The expert panel came to consensus on the *TpIP stakeholder structure* shown in Figure 6.4, which presents a comprehensive institutional structure of a TpIP project in China. The structure consists of six main actors: Host/Consumer, Third party investor, Source of capital, Sub-contractors, Independent services, and Government/authorities.

Figure 6.4: TpIP stakeholders Structure (Author's own)

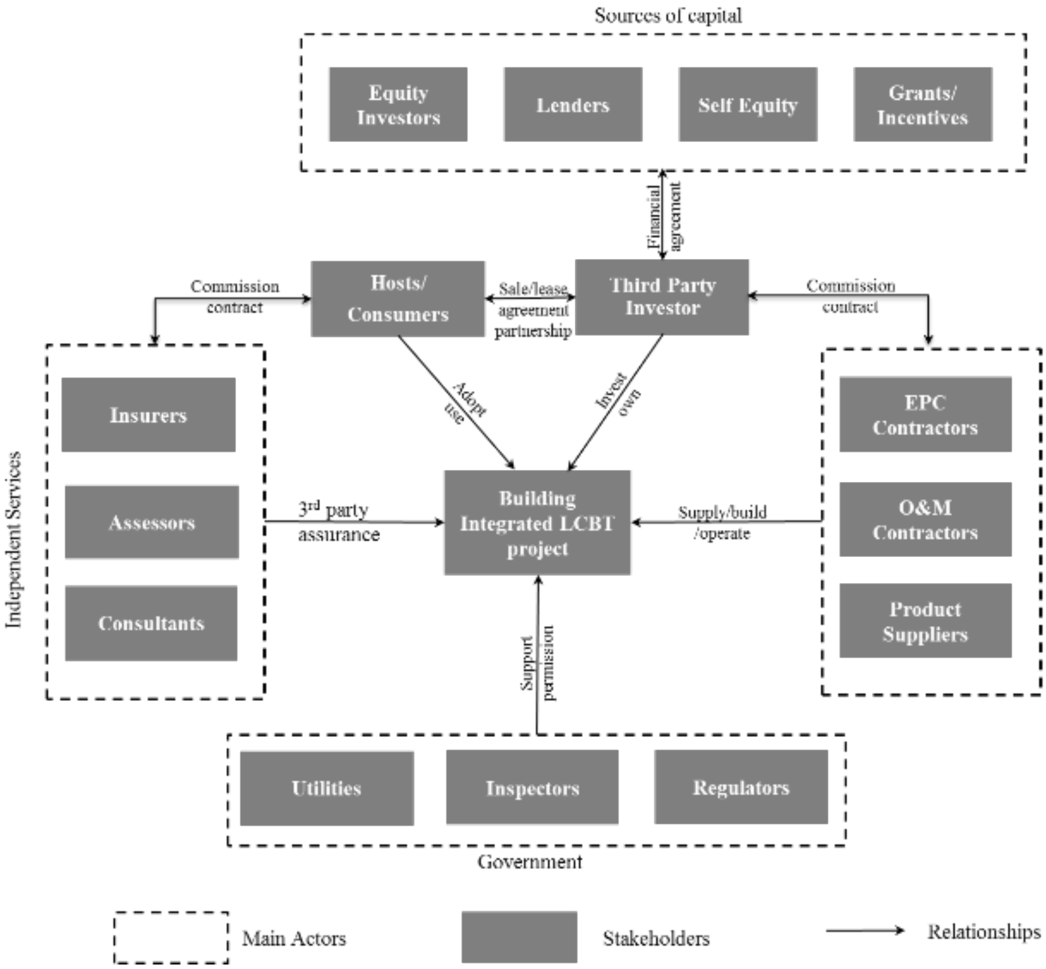


Table 6.5 explains the roles and responsibilities of the main actors, and their current status in China:

Table 6.5: LCBT project TpIP main actors (Author's own)

Main actors	Roles & responsibilities	Current status in China
Host/Consumer	Initiate demand Provide installation space and commit to long-term collaboration	Weak
Third party investor	Leading role of TpIP Investor and owner of LCBT project, and willing to share benefits	Emerging business

Source of capital	Provide funds/long-term loans and preferential interest rates	Lack
Sub-contractors	Accredited contractors provide quality services and products	Trust problem
Independent services	Third party assessor, advisor, insurer provide independent professional services Provide assurance to projects, and reduce risks	Lack
Government/authorities	Political driver provide enabling policies and incentives, foster health, fair and competitive market, allow market access for private investors, encourage innovations	Increasing support, but big subsidies fund gap, and lagged regulations

6.4.2 Financial aspect

The analysis results indicate that the main concerns in the financial aspect are related to investment return and financing means. Investment return can be measured through creation of financial models and financing means can be determined through a financing mechanism.

Table 6.6: CSFs Refining for Financial aspect

Initial financial CSFs	**Feedbacks**	**Modified CSFs**
FF01 - Financial benefits for users	This is negotiable for customers if the project can bring other non-financial benefit (D01) It is a key factor for increasing demand (C01 & D03	**F01 - Benefits for customers**
FF02 - Low project financing cost for investors	Long-term and low-cost capital is essential if investors use financing means for project developments. Currently, only state-owned and some large public listed companies	**F02 - Low cost financing**

	are able to obtain below market benchmark rate (C01 & D03)	
FF03 - Investment payback	This is the top priority of project investment. If a LCBT project wants to attract third party investors, it has to make money (C01 & G01)	**F03 - Acceptable financial return on investment**
FF04 - Access to financing sources	Currently commercial loans is the main source of financing. The government (C02, D01, D03)	**F04 - Access to financing sources**
Other CSF	Government subsidies are important for promoting adoption of LCBTs, particularly at the beginning of the market development (C01 & G01)	**F05 - Government subsidies**

A financial model for LCBTs investment should show a good financial arrangement that benefits all parties. First of all, the investment should be financially attractive to investors. One participant states "*Investments are based on the net present value of the lifecycle cost of the LCBTs*" (I01). Another participant emphasizes "*potential profits or losses should be measurable and used for the feasibility study of the specific LCBT investment*" (D03). "*Investors need to find ways to secure reliable revenue streams while minimizing costs*" (I02). Secondly, the project should be financially attractive to the host, i.e. developer or owner. "*It move the capital cost (of low carbon energy equipment) out of building project and a low carbon energy generation and supply system can be ran separately by a third party*"(D02). Establishing a partnership agreement and providing trading price on energy supply puts hosts' (developer, owner, and tenant) costs at or below the cost of a conventional building. In addition, indirect benefits should be presented with evidence. "*High performance buildings help sale better or higher rents*" (D03). Thirdly, "*the project should also be financially attractive to tenants, for example, the cost of energy consumption is lower than conventional building, and the occupiers live in a healthier and more comfortable building*" (D03). Overall, it should show attractive investment opportunities. A long-term strategic partnership relationship between key actors enhances credibility and generates a steady return. "*We* (*the TPI) see the investment partnership as a long-term strategic* *business choice" (I02)*. Finally, the business case should prove risk reduction and return advantage of the investment. "*Low carbon building energy is seeing rapidly increasing demand and decreasing cost" (I02).*

Financing is a key measure to accelerating investment in adoption of LCBTs, addressing the high capital expenditures preventing the market from realising its full potential. Capital-intensive LCBT projects generally have long-term payback and high risk characteristics and investors' self-funding is finite for scaling investments. Investors need project finance loans with lower interest rates and longer term lengths. A proper financing mechanism can provide patient capital for such investments. Pension funds, China policy bank, insurance companies or green funds can be potential patient capital providers (C02). Other potential sources of patient capital can be investment banks or dedicated funds to low carbon building technologies (G01). The recently emerged internet financing, such as crowdfunding, has been used for BIPV projects in China. China has been providing low-interest loans for rural BIPV projects. These loans are provided at around half the commercial interest rate and have supported a variety of renewable energy projects for electricity access in rural areas (Li, 2018).

Other CSFs include government subsidies, which are are important for promoting adoption of LCBTs, particularly at the beginning of the market development (C01 & G01).

6.4.3 Legal aspect

According to the TpIP stakeholder structure discussed in Section 6.4.1, a third party investor for a LCBTs project can propose a sale/lease agreement with the host party involving partial/total investment and equipment leasing and may use a Design-Finance-Build-Operate (DBFO) model in the project. In addition, the third party investor may establish contracts with multiple parties. For example, they can enter into a partnership with utilities to mitigate project risks and enter financial agreements with financial institutions to gain upfront capital. They can also benefit from the flexibility of collaborating with equipment manufacturers or technology providers to reduce project risks and operational costs. They can initiate a risk-sharing and benefit-sharing mechanism to allocate the responsibilities and incentives of LCBTs developments among project stakeholders. The success of TpIP agreements relies heavily on external market mechanisms, in which the energy produced from the installed LCBT can be realised. On one hand, the internal contracts are designed around the external policy and market conditions, while on the other hand, the required conditions also inform policy and market to make changes and improvements.

This study analyses the legal CSFs from two angles: internal and external. The internal legal CSFs are in relation to the legal agreements and structure between project parties. The external legal CSFs are the relevant regulatory and legislative supports/rules that provide an enabling environment.

Internal legal aspect:

Table 6.7: CSFs Refining for legal aspect

Initial legal CSFs	Feedbacks	Modified CSFs
LF01 – Company credential system	Choose large, reliable companies (D01) Establish long-term trust collaboration (D02) Third party certification (D01) Establish credential system company information platform (C02)	**L01 – Credibility and transparency**
L02 - Insurance mechanism	Improve quality control (D03) Include conditional contract clause to prevent economic lost (C02) Bring in insurance company (I02)) Third party guarantee (I01)	**L02 - Insurance mechanism**
L03 - Government policy	Joining government demonstration programme can offer preferential policy (I02) Government provide additional inspections and administrations (D01)	**L03 – Join in government programme**

	This factor is also under external enabling conditions	
L 04 - Clearly defined ownership	Project due diligence including property ownership and land/roof space usage right (I01) Ensure all legal rights (D03)	**L04 - Clearly defined property ownership and usage rights**
L05 - Roles and responsibilities	Explained in Table 6.10	**L05 - Clearly defined roles and responsibilities**
Additional factors	Need flexibility and innovative contract The legal aspect of these model needs extra attention (I02) Innovative models such as Internet+ models, centrally optimised systems, peer-to-peer energy and blockchain (I01) Define shared liability makes parties work together (D01) Shared risks (I02)	**L06 - Flexibility and innovative contract** **L07 - Shared liability**

Challenge: Reform of the current energy industry is needed.

The TpIP model on electricity production in buildings faces a legal challenge under the current energy industry in China. In China's utilities market, where state-owned utilities are granted monopoly rights for selling electricity, China's regulations or legislation may prohibit private companies who own renewable energy generation systems from selling electricity. For developers wanting to use the third-party PPA model, it would require that they be regulated by the state. Regulation of third-party owned systems would add administrative costs and development time to projects, making this finance model less economically appealing. Third-party-owned systems arise in regulated retail electricity markets, where they could be viewed as being in competition with utilities monopolies. Regulations and public policy play a central role in motivating LCBTs adoption (Zhang, 2016).

6.4.4 Operational aspect

Property development generally is a complicated process and involves multi-disciplinary teams and partners. A TpIP LCBT installation on either new built or retrofit buildings involves interactions with the development and management of the building. For the operational aspect of TpIP framework, the study initially identified five CSFs from the first round of the expert interviews (section 6.3.4), considering both LCBT project development and management and its interactions with project parties and external systems. In the second round of expert interviews, the expert panel gave their feedback on these CSFs. The researcher made modifications according to the feedback data. Table 6.8 shows the modified CSFs for the operational aspect of the TpIP framework.

Table 6.8: Modified CSFs for Operational Aspect from 2nd round of the Experts Forum (Author's own)

Initial operational CSFs	**Feedbacks**	**Modified CSFs**
OF01- Suitable building types	Seeking suitable project buildings is a time and labour consuming process for the third party investor due to information asymmetry and repeated work in project assessment. Investors need building information data for market development. (Synthesis of feedback)	**O01 – Information disclosure for matching LCBTs and building stock** **O02- Simplified process for project initiating stage**
OF02 - Select suitable LCBTs	Selecting suitable LCBTs sometimes is difficult for property developers or building owners due to lack of knowledge and skills. Developers and owners need LCBTs data to initiate adoption programme and need market data to choose qualified companies. (D01)	

Initial operational CSFs	Feedbacks	Modified CSFs
OF03 - Capability of operation team	Good LCBT operation and management skills is key factor of the success of project delivery and operation. It enables low operational cost, hence increased profits. (Synthesis of feedback)	**O03- Capability of operation team**
OF04 - Reduce conflicts in the project	Communication and collaboration are key to reducing conflicts between parties. When there are conflicts in procedures, it requires mutual concession from all parties for a workable solution. (Synthesis of feedback)	**O04- Communication and collaboration** **O05- Mutual benefit objectives** **O06- Optimise procedure**
OF05 - Select suitable parties	This is to prevent the partner company having a shorter life than the contract length. Chinese SMEs have an average life expectancy of 3.7 years (ADB), which does not match the average contract period of LCBT projects. In addition, most Chinese buildings' lifespan is less than 30 years. Existing building stock may have short life left. (Synthesis of feedback)	**O07- Ensure long-term partnership**
Other CSFs	Use of new technologies to improve development and operations, reduce operational costs (I02) Understanding customer needs helps investors improve management, services and quality (D03)	**O08- Reduce operational cost** **O09- End user engagement**

Discussion with the expert panel focused on three areas: project life cycle process, operational cost and interactive collaboration. Operational procedures are required to facilitate the integration of the TpIP model into new build or existing buildings' development and property management systems.

End user engagement factor was added by the expert panel. There has been a fundamental lack of concern about the user's perspectives in the project development process, especially for decision making during the early stage of project planning. The TpIP model can fill the gap by establishing a user engagement process framework. In addition, user engagement can increase public awareness (D01). Moreover, it helps to address users' views and needs throughout the project development process and overcome the clients' acceptance and transparency barriers.

Adopting the TpIP model for LCBTs projects, not only for the early stages of LCBTs integration planning and design but also for construction, operation and management stages can help to establish better risk allocation between owners, investors, developers and users, and to create innovative and cost-beneficial ways to achieve carbon reduction targets for buildings.

The factor of *Communication and collaboration* can bring stakeholders with diverse interests together to tackle the problems during development and operation. The implementation of LCBTs can therefore be valuable to the property developer, building owners and LCBTs providers by moving towards a more client-oriented service production.

6.4.5 Risk Factors

TpIP involves multiple conflicting interests. If risks are not allocated appropriately, the project host may incur costs that it cannot control. The benefits for the TpIP framework should justify the risks involved, in order to be adopted by any business entity. There are a number of risk factors identified through the expert interviews. In the second round of the expert forum, the experts addressed previously identified risk factors and discussed the likely changes that increase the success of LCBT partnership. The feedback and the modification of risk CSFs are presented in Table 6.9.

Table 6.9: Modified CSFs for Risk Aspect from 2nd Round of the Experts Forum

Risk CSFs	Feedback	Modified CSFs
RF01 - Long term operation and maintenance risks	Host parties are worried about LCBT investor and operator not lasting to the end of contract period, or not able to run the system (D01, D02 & D03)	R01 - Long term operation and maintenance risks
RF02 - Financial risks	This is the main concern for all parties. Whether the project can meet the expected financial gain or not is particularly critical for investors. Key variables are interest rate and stable cash flow, other variables are timely payment from bill payer and government subsidies. (Synthesis of feedback)	R02 - Financial risks, identify key influence variables
RF03 - Better risk allocation	Technical risks allocated to the best controlled parties through contracting out to specialised companies. (All participants)	R03 - Better risk allocation
RF04 - Policy risk	As the Chinese market is heavily reliant on policies, this is a critical factor for the success of the low carbon investment. Current experienced risk in the sector is that the subsidy payments are not paid on time, or not paid at all. (I02, D01, D02 & D03)	R04 - Policy risk, identify influencing factors and inform policy
RF05 - Market risk	Different LCBTs have different market risks. See details in section 6.3.4.	R05 – Identify market risks for LCBT
RF06 - Risk control	Establish control measures to eliminate risks. See details below in this section.	R06 - Risk control measures
RF07 - Lack of integrity	This is one of the key risks that the Chinese market is currently facing (C01, C02, D01, D03 & I02)	R07 - Lack of integrity

Long term operation and maintenance risk is an important factor for all parties to consider. Collaborative partnership can help to establish a mutual objective between stakeholders and improves the life of the TpIP project. In the Chinese market, the capacity of O&M teams varies. Most hosts are not experts in LCBT areas. Standardization can improve the capacity of O&M services, providing a high standard of LCTBs performance and reduce learning costs. There may be the possibility that one of the participants goes bankrupt or withdraws from the project. TpIP partners should investigate partnering companies and choose stable and reliable partners.

Balancing Host/Third Party risks and rewards helps reduce financial risk and increases participants' motivation. A LCBT project is normally initiated by one party and contract negotiations are often one sided. The initiator sometimes has to accept a high risk and low reward situation in order to gain contracts. A possible weakness of the model is that the TPI has to bear almost all risks involved in the projects. If market prices or payback periods change substantially, the project could become unviable for the TPI: the partnership should be flexible to ensure all parties make an effort to secure the viability of the project.

Allocation of risk requires many specialists in different fields to work together: the specialists can better manage risks in their own field. To this end, a TpIP network should include professionals from all relevant sectors to participate in the projects.

6.4.6 External enabling conditions

At present, China is promoting low carbon investment and has issued various policies and incentive schemes to encourage private investors to engage with LCBTs deployment. However, based on the current market and policy conditions, investors face economic, system, policy and market challenges in achieving a stable return. Policy makers should be informed of these challenges, so they can be tackled in order to provide a good market and policy environment for LCBTs investment to grow. Currently, BIPV has huge potential through a TpIP model in China. The central government targets signal political commitment to PV energy. It has better external enabling conditions compared with other renewable energy. From a financial perspective, support schemes such as solar feed-in tariffs have been a key enabler for distributed PV markets. However, there are barriers in existing regulation and legislation, which need to change, as shown in the following comments from the expert panel:

Economic problems caused by poorly matched policies (C02, C03, D01 & D03)

Restrictions on third-party access to energy infrastructure (I02)

Market development's heavy dependence on policies (C02, C03, D02 & D03)

The problems of lack of data and information (C03, D01)

The introduction of new players such as third-party investors can be a source of increased competition within markets that have traditionally had very limited competition. To put this competition on a level playing field, a number of changes to policy and regulation will likely be needed. In addition, utilities pricing should be fair, therefore creating appropriate incentives for both consumers and low carbon energy providers.

LCBTs uptake is rarely driven simply by internal factors alone. The overlay of internal and external factors for decision making regarding investments overcomes a wide range of barriers in LCBTs investment.

Table 6.10: Modified CSFs for External Enabling Conditions from 2nd Round of the Experts Forum

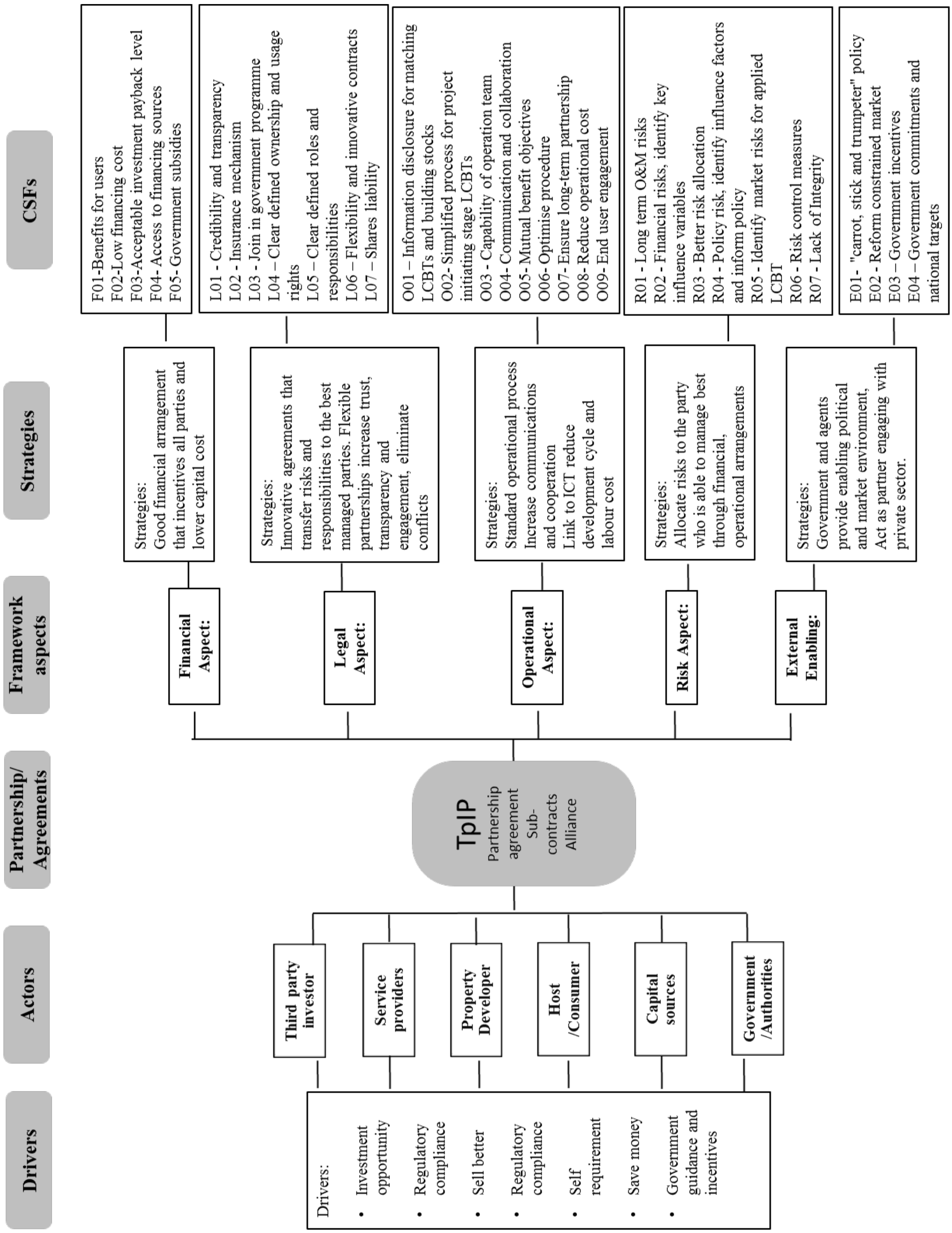
Initial External Enabling CSFs	Feedback	Modified CSFs
EF01- "carrot, stick and trumpeter" Policy	Carrot is incentives, stick is punishment, trumpeter is promotion (D01)	**E01- "carrot, stick and trumpeter" policy**
EF02 - Reform constrained market	LCBTs adoption in energy demand side is under market reform. The reform provides energy market access for private investors in low carbon energy. The private-led investment models also inform policy makers about required conditions. (I02, D03)	**E02 - Reform constrained market**
EF03 – Government incentives	Currently, the LCBTs investments still need government incentives to be financially viable. The aim is to	**E03 – Government incentives**

Initial External Enabling CSFs	Feedback	Modified CSFs
	reduce the cost and eventually achieve a price that can compete with conventional supply without government subsidies (C02, I02, D01, D02, D03 & G01)	
Other CSFs	Government commitment is a key driver for business (D01, D02, D03, I02)	**E04 – Government commitments and national targets**

6.5 Validating TpIP Framework

The results of the second round of expert interviews validate the contextualised TpIP framework presented in Figure 6.5 below. The expert panel reached consensus on the framework.

Figure 6.5: Final Conceptual TpIP Framework Validated by Expert Forum (Author's own)



Building developers or owners' capital is not required for additional LCBTs features on their building projects, therefore, this remains available for other investments. This removes competition for capital between low carbon building projects and conventional building projects. Hosts bear minimum financial risk and no extra cost for the adoption of their chosen LCBTs. Furthermore, participating companies can remain focused on their core business or are only required to contribute minimum human resources to collaborate with the operation of the project. These benefits of the TpIP model have also been confirmed after communication with the expert panel. Trust, motivation and commitment issues are overcome.

6.6 Chapter summary

This chapter describes the contextualised TpIP framework developed through the two-round expert forum method. 10 experienced experts from China participated in the expert forum process. During the first round of the expert forum, the researcher conducted semi-structured interviews with each participant individually. Through analysing the interview data, the study identified 6 drivers and 16 barriers for LCBTs investment in China. The study also identified 23 CSFs using the FLORE analytical framework. Moreover, a stakeholder structure for TpIP is presented. As a result of this stage, a TpIP framework encapsulating the identified CSFs, drivers and barriers was drafted and sent to the expert panel for feedback. In the second stage, participants' feedback on the draft conceptual framework was collected and synthesised. Thereby, the TpIP framework was adjusted and validated according to the feedback from the second round expert forum.

At this stage, the framework is a conceptual model. The structure of this model can be further developed into a specific detailed framework for given projects. In the next chapter, the framework is tested and refined to a detailed framework through case studies research.

Chapter 7 Developing Detailed TpIP Framework through Building Integrated Photovoltaics Case Studies

7.1 Introduction

The previous chapter explored and developed a contextualised TpIP framework for China through a structured expert forum process. This chapter investigates in detail how this framework can be tested and validated using multiple case studies to further develop a detailed TpIP framework. As explained in the Methodology chapter, this study aims to develop an in-depth project-based framework, rather than a general framework for wider scope (Section 5.3.4). This enables the study to draw a deep understanding of the TpIP framework adoption in empirical projects. According to the earlier finding in this thesis, among all the mature LCBTs, distributed photovoltaic (DPV) electricity generation has the most success potential for TpIP adoption in the current market situation of China (Section 6.4). Therefore, this research uses BIPV (including BIPV) projects as case studies to test and validate the TpIP framework.

In this chapter, the study uses the FLORE classification of the conceptual TpIP framework, developed in Chapter 6, to analyse the case studies. The case study analytical structure consists of the main components of the FLORE model (see Figure 6.5). It is applied to the case studies as an analytical structure to explore different TpIP aspects of the private sector-led BIPV adoption projects. First, in terms of external enabling conditions, because all three case studies used the same LCBT (BIPV) and were located in the same region (south China), the three common contextual aspects of the case studies are analysed before the study goes into the details of each individual case project. Firstly, selection of case projects and methods of data collection are described in Section 7.3. Secondly, Section 7.4 describes each case study project and presents the data and findings in a structured form. In terms of stakeholder relationships, each case study starts with a description of the project's profile, stakeholder structure, actors' roles and responsibilities and motivations. Then, four different inter-organisational aspects are analysed: financial; legal; operational; and risk. Furthermore, section 7.5, based on the cross-case analysis of all three case projects, draws combined results into a detailed TpIP framework. Finally, the results of this detailed TpIP framework was sent to the expert panel for validation (Section 7.5.6). Section 7.7 summarises the conclusions of the case studies.

By analysing the case studies with this set of structures, the study can test and refine the TpIP framework developed for Chinese private sector-led low carbon building projects. From a project point of view, it enabled the researcher to identify CSFs that lead to the success of the project, how they are performed and how they can be positioned within and between the different elements and aspects in the framework.

During the course of this research, the PV industry in China has grown rapidly. Due to the dramatic changes in both policy direction and market environment, some obstacles identified in the early stage of the research, such as grid connection, are no longer a problem. Meanwhile, new challenges, such as electricity sales reform, have emerged along with the change of technologies and new regulations. Therefore, it is necessary to discuss the changing background of China's DPV and BIPV in this case study.

7.2 Selecting BIPV case study projects

Chapter 5 (Section 5.4.7) of this thesis has discussed the design of multi case studies for the development of a refined TpIP framework. According to the suggestions from the expert forum (Chapter 6) and literature review on China's low carbon building sector (Chapters 3 & 4), this study uses Chinese BIPV projects as case studies, to refine and validate the TpIP framework.

7.2.1 Selection of case study projects

Before selecting case study projects, a selection criteria needed to be formulated. Having reviewed the current situation of the BIPV market in China (see section 4.2.2), the study sets the scope of case studies within commercial and industrial buildings. The case projects should have the following criteria:

- Commercial and industrial building with large roof space
- Single ownership building

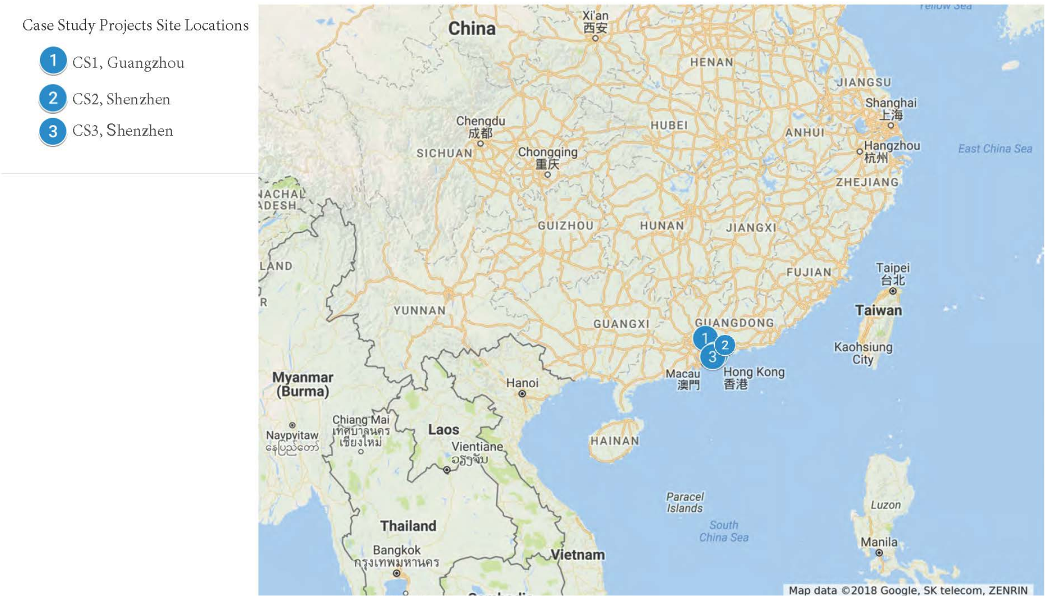
- Solar PV system is financed and built by third party
- Projects are completed or close to completion
- Data are available and accessible
- Locations are in the same climate zone and easy to reach

The researcher has several years of work experience and a good network of resources in the low carbon building sector in south China. Initially, there were a list of five potential BIPV projects in Guangdong province suggested through the expert forum contacts and snowball method. Having consulted the project owners and reviewed the project profiles against the selection criteria, three case projects were confirmed to participate in this study. The owner of the projects signed the Consent Form (see Appendix 6). The names of the projects are anonymized in this thesis. Table 7.1 displays the profile of these three case studies, one is a industrial premises, one is a supermarket and one is multi-storey office buildings. All are located in Guangdong province, the biggest GDP contributor among all provinces in China since 1989. Figure 7.1 shows the location of the projects.

Table 7.1: Profile of Case Study Projects (Author's own)

Code	CS1	CS2	CS3
Building type	Industrial	Supermarket	Offices
BIPV capacity	3.66MW	404.80KWp	0.5MW
Current models	EMC+PPA	EMC+PPA	EMC+PPA+EPC
Completion year	2014	2011	2016
City	Guangzhou	Shenzhen	Shenzhen

Figure 7.1: Locations of 3 BIPV Case Study Projects in South China (Created from Google map by author)



7.2.2 Data collection framework

The field work for the case studies took placed between May 2015 and September 2016. The data was collected through site visits and observation, document review and semi-structured interviews. A data collection framework was established to guide the conduct of case studies activities. The framework consists of a set of topics, from which the researcher needs to collect information and investigate answers in order to conduct a systematic case triangulation and cross-case analysis.

The researcher prepared a list of required documents and interview questions in relation to the topics (see Appendix K – *Case Studies Interview Guidance* for detailed guidance). The interview questionnaire contained questions addressed to relevant staff of the participating firms in relation to the topics from different participants' points of view from the three project sites. Furthermore, the study consulted predictions and censuses from the expert forum, contributing to findings, hence, further validating the practical application of the TpIP framework.

7.3 Case studies findings

7.3.1 Case study 1: Rooftop PV electricity generation on industrial buildings in Guangzhou

7.3.1.1 Project description

Table 7.2: CS1 Project Profile

CS1 Rooftop PV electricity generation	
Completed year	2015
Location	Guangzhou, South China
Total installed capacity	3,564.90KWp
Annual electricity	3,305,900 KWh/year
Type of Contract	EMC Power Purchase Agreement
Innovation	China's first use of BIM technology on BIPV

Date collection sources

Site observation

1. CS1-Company B Shenzhen office BIPV project and technical team
2. CS1 Rooftop PV electricity generation site (Figure 7.2, Figure 7.3&Figure 7.4)
3. CS1-Company A administration offices and power control room (Figure 7.6)

Documents reviewed

1. Application of BIM in BIPV Project, 2016, Solar Electricity Generation (Published paper provided by CS1-Company B, see Appendix H)
2. Monitoring data of Company A BIPV electricity generation 2014 (provided by CS1-Company B)
3. CS1-Company A (China) Sustainability Annual Report 2014, 2015 & 2016
4. CS1-Company A official website
5. CS1-Company B Annual Report 2015 & 2016
6. CS1-Company B official website

Semi-structured interviews

1. (CS1-01) Manager of Energy Conservation Office CS1-Company A
2. (CS1-02) CS1-Company A property & power management officer
3. (CS1-03) CEO of CS1-Company B
4. (CS1-04) CS1-Company A BIPV Project coordinator
5. (CS1-05) BIM R&D Director from CS1-Company B
6. (CS1-06) CS1-Company B BIPV designer

Project description:

The CS1 rooftop solar PV project is installed on the industrial buildings within a manufacturing site of Company A, with a total installed capacity of 3564.90KWp. It uses 13,980 photovoltaic modules, occupying the roof areas of two office buildings and one industrial building. See Figure 7.5 below for the locations of the 2-phase BIPV project within a motor manufacturing plant. The annual electricity generation can reach up to 3,035,900 KWh under the premise of attenuating the efficiency of the module by 8%, the system operating life is 25 years and the total power generation is expected to be 75,877,000 KWh. The CS1 BIPV project is developed in 2 phases, with a total investment of more than 30 million yuan. The first phase (Figure 7.3**Error! Reference source not found.**) was commissioned in October 2014 and the grid connection was completed in July 2015. The power generation has reached 23.31 million kWh, using the roof space of about 15,000 square meters. The second phase (Figure 7.4) of the project is located on the roof of the two concrete structured buildings and was installed and connected to the grid in 2015. After the completion of the project, it is estimated that the annual power generation can provide 8.6% of the company's total electricity consumption, equivalent to 232 tons of standard coal reduction, 1,736 tons of carbon dioxide emission reduction and 95,000 trees.

Figure 7.2: 2-Phase BIPV Project Installed on an Industrial Site (Created from

Figure 7.2: 2-Phase BIPV Project Installed on an Industrial Site (Created from Google map)

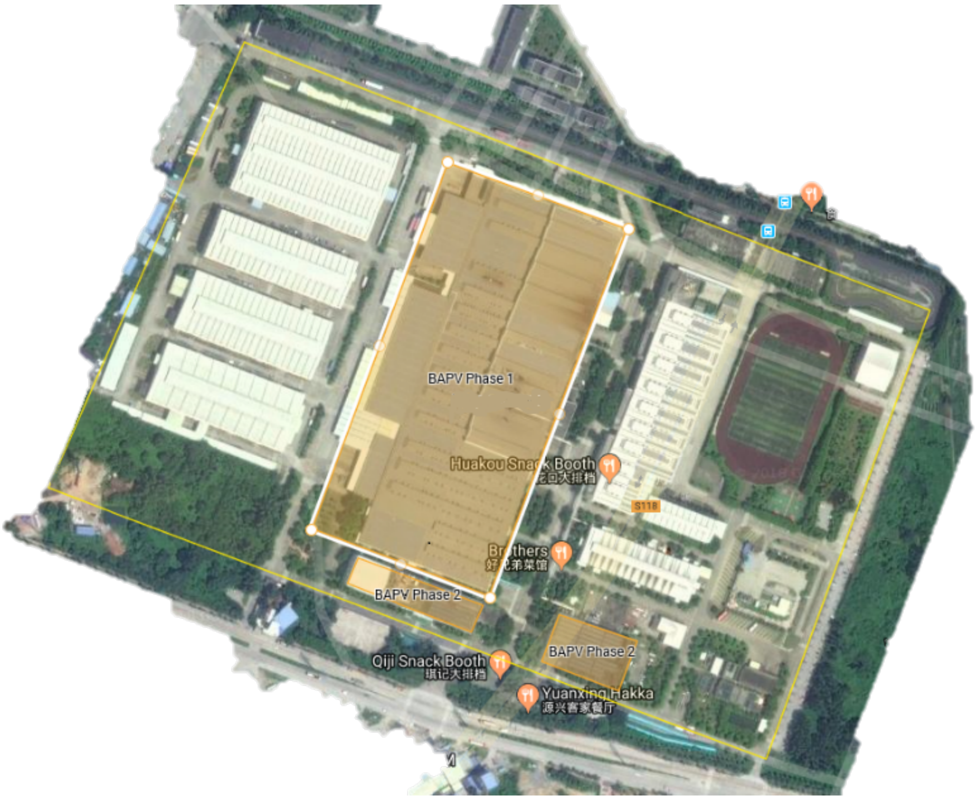


Figure 7.3: CS1 BIPV Power Station Phase 1 on Colour Steel Tile Roof (Photo by author)

Figure 7.4: CS1 BIPV Power Station Phase 2 on Concrete Flat Roof (Photo by author)

The project adopts the EMC power purchase method and is funded and constructed by Company B. The host company A only needs to provide the roof space for the installation of PV system and purchase the electricity generated by the photovoltaic project. The photovoltaic electricity price is 85% of the retail electricity price.

Company A is a joint venture of Chinese and foreign motorcycle manufacturers in China. In 2006, the manufacturing plant moved to this new production site in Guangzhou, which has a floor area of 320,000 m^2 and a building area of 100,000 m^2 with a production capacity of 1 million units. The site was built in line with the company's Green Factory concept, which introduced various energy-saving and eco-friendly facilities. Company A launched a new Energy Conservation Office dedicated to environmental action. The Office initiated a set of programmes in order to achieve the company's carbon dioxide emissions reduction targets under its sustainability plan. By 2015, it reduced carbon dioxide emissions on a per-unit basis by more than 40% from 2010 levels and also reduced absolute energy use by nearly 30% (source: Company A's Annual Report, 2016).

Company B is the investor in the CS1 BIPV power generation project. Company B is an integrated construction engineering company providing integrated services of designing, constructing, installing and technical services for BIPV projects and hi-tech energy-efficient building peripheral structure. Since 2003, the company has put in significant manpower and resources into researching and developing energy-saving and building-integrated solar energy generator, and has established a R&D centre (source: Company B's brochure and interview with CS1-03).

CS1 is China's first use of BIM technology on BIPV power generation projects. Company B used BIM (Building Information Modelling) management technology throughout the CS1 project development from the main structure of the modelling, roof photovoltaic system design, construction simulation and PV system operations, so that the entire life cycle of the project can achieve visualization, coordination, simulation, optimization and feasibility. Figure 7.3 shows the CS1 rooftop solar PV array and weather monitoring station, through which data is collected, monitored and transferred to the remote centre (source: site observation, document review and interviews with project team).

Figure 7.5: CS1 Rooftop PV Power Station phase 2 PV Array and Weather Station (Photo by author)

Figure 7.6: CS1 Rooftop PV electricity generation Monitoring System (Photo by author)

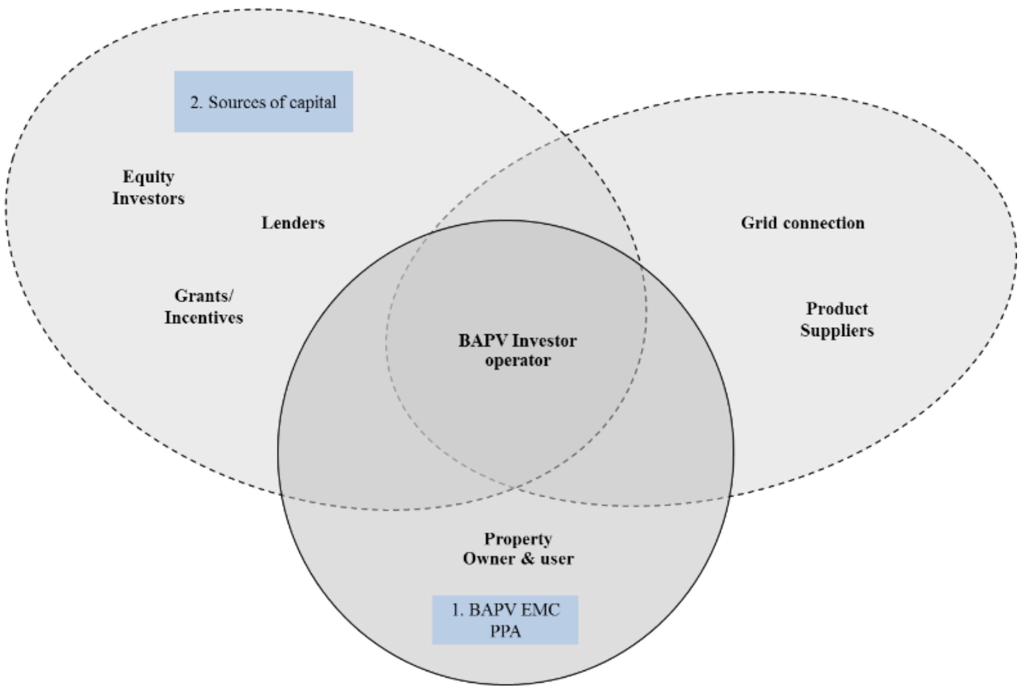
7.3.1.2 Stakeholder relationship

The project adopts the EMC method. Company B invests in and constructs the PV. The host company A provides the roof space for the installation of the PV system and purchases the electricity generated by the photovoltaic project with a price 85% of the retail electricity price. Company B receives the money from selling electricity and from state and provincial government subsidies. Company A owns and operates the properties and the premises are managed by its own property management department. The EMC is signed between Company B and Company A. Company B established a subsidiary project company, which takes the responsibility of project delivery, operation and maintenance. The two parties agree roles and responsibilities. See Table 7.3 for project participants' roles and responsibilities.

Table 7.3: CS1 actors' roles and responsibilities

Actors	Roles	Tasks & responsibilities
Host Company A	Project host Project user	Providing roof space Consume solar electricity and paying bills
Investor Company B	Project Investor, Consultant Financer Subsidies receiver EPC O&M	Design, feasibility study Providing funds Engineering, procurement and construction, Operation and maintenance
Product Suppliers	PV products supplier	Sale PV modules, guarantee production meet promised specifications
State Grid	Grid company	Grid-connection, metering, electricity bill and subsidies calculations
Government	Subsidies provider	Issue subsidies Market inspections

Figure 7.7: The CS1 project stakeholders relationship model



Motivations:

Having interviewed senior level staff in both parties of the CS1 project, the study found that the CSR requirement is the main driver for the project host party and the business development strategy is the key driver for the project investor. Financial benefit is a decisive driving factor for the investor's participation. However, it is not a critical driver for the host.

The main motivation for Company A adopting a rooftop PV power station is the corporate environmental commitment. The national group of Company A has set a five-year carbon reduction plan (2010-2015) and promotes the adoption of rooftop solar energy on their production sites in China. A manager from the Energy Conservation Office of Company A said:

> *We did not consider too much about savings on electricity bills, the main reason for us to do it (adopting solar PV) is the requirements of our company's environmental policy. (H1)*

There are other green features implemented on-site as well, such as innovative production processes, waste and water programmes.

The motivation for investing in BIPV projects for Company A is the company's business direction. The CEO of Company A explained the company's development strategy:

> *Under the state policy of vigorously developing green building and building integrated photovoltaic, our company will expand the scale of distributed photovoltaic power plants investment and construction, increase the proportion of distributed photovoltaic power business in the company's main business revenue, distributed photovoltaic investment and management business will become the company's future business structure optimization and upgrading focus point. (H3)*

Both Company A and Company B publish a Sustainability Annual Report every year.

7.3.1.3 Financial aspect

Both Company A and Company B have gained financial benefits from the rooftop solar PV project. Company A saves 15% on the energy price for the electricity generated from the PV power plant. Company B receives revenue through electricity sales and government subsidies. The electricity tariff to the consumer is higher than the feed-in-tariff to the state grid. The higher the proportion of PV electricity consumed by the user, the higher the income generated to the investor. If Company A consumes all of the electricity generated from the rooftop PV plant, the investment payback period will be about 7 years. If all PV electricity is sold to the grid, then the payback period will be 9 years. The electricity generated from this PV plant only accounts for 8.6% of Company A's total electricity consumption. It is likely that all PV electricity would be consumed by the host. PV projects are capital intensive investments. Company B raises its investment funds through bank loans and the stock market. Company B became a public listed company in 2014. This provides significant funds for Company B expanding the scale of PV investment business. This PV project brings a long-term stable income for the company and has shown a good financial value in the company’s accounts.

China’s PV subsidies have not always been delivered on time. The "feed-in tariff", for example, has sometimes been paid late to solar investors. "*The government is often a year or longer period late in delivering the FiT subsidies for the electricity generated from PV plants, that causes financial troubles on a project*," says one interviewee.

The researcher asked the interviewees from both parties to give their opinions on the financial CSFs identified from the expert forum (Chapter 6, Section 6.3.5) and to suggest modified and/or other CSFs based on the experience of Company A’s PV project. Having analysed interview results and the status of this case project, the financial CSFs are explained in Table 7.4 below.

Table 7.4: Financial CSFs for Case study project 1

Financial CSFs	Project measures and indicators	Refined CSFs
F01-Benefits for customers	15% discount on market price	**Saving to clients**
F02-Low financing cost	Company B uses corporate financing. The sources are bank loans and equity investment. The financing cost is close to market benchmark level	**Low cost financing** (currently only state-owned companies and large companies are able to get below market benchmark rate)
F03-Acceptable investment payback level	*IRR=13% Payback period=7years	**Attractive investment payback**
F04 - Access to financing sources	Equity investment Bank loans (short-term) PV subsidies	**Appropriate financing sources available** (The current financing means are limited and not suitable for long-term payback investment. More flexible financing sources should be available to meet different needs) (High liquidity risk when company uses long-term returns to cover short-term loan)
F05- Government subsidies	2014 standard: State subsidies (0.42 yuan/unit) to electricity generated for 20 years, plus local government electricity subsidies (0.1yuan/unit) for 10 years	**Good subsidies model** (Good subsidies model can encourage high quality and efficient products, foster competitive and healthy market, aim for energy parity without subsidies)
Other CSF	Guaranteed minimum consumption	**Stable cash flow** (predictable and stable)

*Calculations based on assumptions proportion of self-generation and self-consumption is 100 %, discount rate of sale price for host customer is 15 %.

Overall, the financial analysis of case project 1 shows good investment payback for the investor. The good technical economic indicators and benefit sharing are the main considerations when participants make a decision. Financial mechanisms and government subsidies are critical supporting conditions to ensure the economic payback.

7.3.1.4 Legal CSFs

The legal framework for this project can be classified into internal type and external type. The internal framework includes the EMC power purchase agreement and roof lease agreement between the BIPV investor and the host company. The external legal framework includes the State Council (2013) document and the National Energy Administration *Notice (2013),* encouraging investment in DPV and PV FiT, grid-connection policy and permission, grid collaborations on installation, metering and inspections, and other supporting regulations. These provide enabling conditions for projects. In general, the internal legal framework should be designed and comply with the external legal framework. However, the case study shows that the external legal conditions are developed behind industrial practice in China. For instance, the EMC electricity purchase model used in this project is encouraged by the Government. However, the related electricity market law has not given legal rights to the private PV investor for selling electricity to consumers at the time the project started. Until 2015, China's State Council issued No. 9 document for new power market reform, confirming further opening up the electricity supply market, and power purchase agreements gained legal status for electricity supply services in China. This external legal framework is important for the success of the project. Table 7.5 below shows the legal CSFs analysis for the case study.

The analysis of the legal aspect of case study 1 shows that a good legal framework is needed for project success. Not only the internal legal issues but also the external legalisation should be examined carefully before entering a development. Establishing trust and collaborative partnership is essential: the parties need to maintain good relationships. However, lack of an industrial insurance mechanism makes potential dangers hidden in the project, which have not been resolved.

Table 7.5: Legal CSFs identified from Case study project 1

Legal CSFs	Project measures	Refined CSFs
L01 - Credibility and transparency	Choose large, reliable project partners. Use of stock market information disclosure system Both parties are public listed companies, the company information is transparent and open to public	**Credibility and transparency** (Use of stock market information disclosure platform for public listed companies)
L02 - Insurance mechanism	Improve quality control Including conditional contract clause to prevent economic lost	**Insurance mechanism** (Performance guarantee in EMC and product specification warranty from product supplier)
L03 - Join in government programme	Project filling and local government support	Local government demonstration project
L 04 - Clearly defined ownership and usage rights	Single owner/tenant building with clear ownership Lease contract for roof usage right Government filing	Clearly defined ownership and usage rights
L05 - Roles and responsibilities	Defined in EMC agreement	Clearly defined responsibilities

7.3.1.5 Operational CSFs

Technology innovation and smart management are used for this project. The project is China's first use of BIM technology on BIPV power generation projects throughout development and management from planning and design to construction.

Company B invested in a BIM application R&D centre to develop Smart Construction (SC) technology and application. According to the introduction by a Company B technical manager, Smart Solar includes planning and analysis systems, intelligent design systems and intelligent management systems. At the site inspection stage, it uses GPS to locate projects and determine project boundaries. The software will automatically calculate and produce the investment plan. It can save 30% of the project cycle time in project management. The quality tracking function of the management platform enables the installation to achieve a high level of quality. The intelligent operation and maintenance system based on big data analysis effectively improves power generation efficiency and operation and maintenance efficiency.

Smart operation and maintenance improves the electricity generation efficiency of PV power plants, reduces operation and maintenance costs and ensures the benefits of photovoltaic power plants.

The analysis of the operational aspect of case project 1 shows successful project development and management procedures, with simplified, duplicable and innovative characteristics. A well-maintained collaborative relationship between the two parties contributes to the success of the project. All the CSFs are verified.

Table 7.6: Operational CSFs identified from Case study project 1

Operational CSFs	Project measures	Refined CSFs
O01 – Information disclosure for matching LCBTs and building stocks	Both parties located in the same region and are well-known companies. It is easy to gain project and company information	Information disclosure for matching LCBTs and building stocks
O02- Simplified process for project initiating stage LCBTs	The PV system investor invented a Smart Solar (SS) 3.0 application, which can quickly produce a plan and calculate investment return for decision making	Simplified process for project initiating stage LCBTs
O03 - Capability of operation team	The investor is specialised in BIPV, has in-house teams for design, EPC and O&M, also established its own R&D centre	Capability of operation team

O04- Communication and collaboration	Working in partnership, the investor remotely controls and manages the system, integrated the monitoring system into the host management system, routine communication and collaboration effectively reduce risks and cost	Communication and collaboration reduce risks and running cost
O05- Mutual benefit objectives	Project performance impacts the interests of both parties (saving and revenue)	Mutual benefit objectives motivate collaborations
O06- Optimise procedure	IT integrated operation system Enable investment to scale up	Technology innovations optimise project procedure
O07- Ensure long-term partnership	Both are large and reliable companies	Secured long-term partnership
O08- Reduce operational cost	Technology innovation and smart management	Standard and replicable procedures reduce operational cost and enable scale-up
O09- End user engagement	The host is also the end user	End user engagement

7.3.1.6 Risk allocation

The main strategy for the risk aspect is to allocate risks to the party who is able to manage best. While the solar EMC model seems attractive to the host customer, many project risks have been transferred to the third party investor. Although the project investor may be the party to manage best and retain complete control across the range of project activities by a non-risk sharing arrangement, it carries the entire risk of the project and the burden for managing it (HOUGH, 1997). This is confirmed by the third party investor of this case project (H3, H4).

The study examines the risk allocation in the case project through analysing the risk aspect CSFs. The findings are presented in Table 7.7 below:

Table 7.7: Risk CSFs identified from Case study project 1

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
R01 - Long term operation and maintenance risks	The risks of this factor include: the O&M team does not have the capacity leading to poor performance of the system or the managing company goes bankrupt during the contract period The risk is allocated to the investor (Company B) who has the expertise and good track record in this fields	Long-term operation and maintenance risks controlled by reliable and qualified parties
R02 - Financial risks identify key influence variables	Liquidity risks. Banks tends to be short-term (1-5 years) Risk of non-performance on the part of host customers (i.e. non-payment of the PV power tariff) Late government subsidies payment	Financial risks Liquidity risk is unsolved for SMEs Stable and high-energy consumer reduces risk of non-performance of host Reach retail parity, no need of subsidies
R03 - Better risk allocation	In current EMC model, the investor carries the entire risk of the project financing, development and O&M	Better risk allocation The investor takes the risks within its expertise and subcontracts non-controllable risks to professional contractors
R04 - Policy risk, identify influencing factors and inform policy	This risk relies on external influence, i.e. national and regional government This risk is low for this project. The project is filed in Guangdong DPV filing system and guaranteed fixed subsidies for 20 years The energy price in Guangdong province is higher than other provinces and policy implementation is relatively prompt	Policy risk; unstable, temporary and unforeseeable policies; subsidies and implementation vary in different provinces and cities National and local policies and incentives are improved and more effective through lessons learnt from industry practises

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
R05 - Market risk, identify market risks for applied LCBT	Solar PV market risk The case study faces: making the solar PV project profitable and lowering operational risks needing a more stable market	Market risk Innovations in technology and management model Innovative financing channel Reform in energy demand-side market (External enabling conditions)
R06 - Risk control measures	Grid-connection service may not be well implemented	Risk control measures See countermeasures for each risk factor above
R07 - Lack of integrity	The case study participants are reputable listed companies with lower integrity risks	Lack of integrity Trust and reliable project partners

In this case, the investor takes on the most risks from all aspects of the project, while the host bears fewer risks. The investor takes measures such as innovations in the technology and management model, and engages in subcontracts and partnerships to reduce risks. However, financial risk, e.g. the cash flow pressure, is still an unresolved risk for the investor's project rolling.

7.3.1.7 Challenges

The main challenge of the TpIP model of BIPV projects is the financial risk for the investor, in particular the cash flow pressure for the PV project investor. Currently, the investor uses long-term revenue (sale of PV electricity) to repay short-term return loans. The large capital requirement for the BIPV project rolling hinders the company expanding its business. BIPV projects are financed through corporate financing and the liquidity risk remains unresolved for growing investment.

7.3.1.8 Summary of case analysis

In summary, the CS1 project demonstrates how the TpIP model is able to satisfy not only Company A's CSR goal requirement but the project implementation and operation via EMC, in such a way that enables them to achieve the corporate's carbon reduction targets. The third party investor (Company B) is under corporate transit from traditional EPC to investor and operator with high capability and skills. However, Company B has to battle against the barrier of cash flow pressure, which hinders Company B's project rolling potential. The Chinese government has been promoting DPV investment and development in recent years. The financing challenges that the project participants are facing will inform government about how to take countermeasures providing external enabling conditions to BIPV projects. The host company's CSR commitment, investors' business needs and national and local political targets are the key drivers to the success of the BIPV project. The third party investment model is being duplicated and applied to other Company A BIPV projects in China (Company A, 2016).

7.3.2 Case study 2: Rooftop PV electricity generation on supermarket in Shenzhen

7.3.2.1 Project description

Project Profile

Table 7.8: CS2 BIPV Project Profile

CS2 Supermarket Roof BIPV Project	
Completed year	2011
Location	Shenzhen, China
Total installed capacity	404.905KWp
Annual electricity generation	450,000 kWh/year
Type of Contract	EMC Power Purchase Agreement
Innovation	The first non-state-owned solar BIPV project under the China Golden Sun Demonstration Programme Government subsidies: 9 CNY/w

Data collection source

Site observation:

1. CS2 BIPV generation sites and utility control room
2. On-site and remote management and monitoring system
3. Company B Shenzhen project office

Documents reviewed:

1. CS2 BIPV Project Brief (Appendix I, provided by Company B)
2. CS2 BIPV Installation Design Plan (provided by Company B)
3. PV electricity generation data of CS2 BIPV (provided by Company B)
4. Company A (China) official website and Company A Sustainability Report (2017)
5. Company B official website and Company B Annual Report 2014 & 2015

Semi-structured interviews:

1. (CS2-01) Manager of Company A supermarket (telephone interview)
2. (CS2-02) Company A supermarket property management officer (face-to-face interview)
3. (CS2-03) CEO of Company B (face-to-face and online interviews)
4. (CS2-04) Company B project coordinator for CS2 BIPV project (face-to-face and online interviews)
5. (CS2-05) Company B BIPV project designer (face-to–face interview)

Case description

The CS2 rooftop solar PV system installation capacity is 404.905KWp, using a total of 1723 of 235Wp polysilicon photovoltaic components and 4 100KW grid inverters, 8 DC convergence boxes, 2 sets of photovoltaic power distribution cabinet and 1 power distribution access cabinet. The system connected to the grid through integration into the building's low-voltage distribution network. The solar PV installation covers 30% of the store's roof space (4,800 m^2) and provides an annual output of 450,000 kWh/year, accounting for about 18% of the store's electricity demand. The system can save 139 tons of coal per year and about 397 tons of CO_2 emissions.

The CS2 supermarket building is Company A's first store in China since it entered China in 1996, and it is also the first retailer in China to install grid-connected rooftop solar photovoltaic power generation systems. Company A is an international retail corporation that operates a chain of hypermarkets and stores. The company has committed to be supplied by 100% renewable energy globally in its 2018 environmental statement. As of 2017, it achieved the world top position for both total number of on-site solar installations and on-site solar power usage (2018 Global Responsibility Report). Company A started to implement an energy efficiency program in its China premises in 2008. BIPV application on commercial buildings was rare in China at that time. The programme team took four years of preparation and huge efforts to make the project happen. This project is the first non-state-owned Golden Sun Solar Demonstration Project (Company A’s document, 2016).

Company B is a green building construction and engineering company providing design, construction and maintenance services for green building technologies. The company is expanding its business into a new BIPV investment model and CS2 is the company’s first BIPV investment project using the new business model. The company invests in, installs and operates the CS2 rooftop solar PV system. Company A purchases all electricity generated from the PV system at a discounted rate.

Figure 7.8: CS2 Supermarket in Shenzhen (Photo by author)

7.3.2.2 Stakeholder relationship

Roles and responsibilities

The CS2 BIPV project used an EMC model. The supermarket is owned and operated by Company A. Company A plays both host and user roles in this case project. The rooftop PV power generation was funded, designed, installed, owned and operated by Company B. An EMC agreement was signed between Company A and Company B. Company A provides roof space for the PV installation and purchases the PV electricity it consumes at a preferential tariff (approx. 20% discount on the local retail price). It makes savings of 100.000 CNY per year. Company B receives the Golden Sun subsidies that cover more than 50% of the system cost. Company B are keen on BIPV because it is the company's business development direction. However, they faced many challenges during this project. Company B complained about expending too much effort for too few benefits (W3).

> *The initial difficulty was the drawings of the roof were not available in China, because it is the first Company A store in China, the design of the building were imported from the United States. So, the designer at the (Company B) New York based office made enormous efforts, finally found the unique*

drawing from the US architecture firm. The Institute of Steel Structure of the Chinese Academy of Sciences examined the design drawing, and issued a verification report, which enabled the project to proceed. (W3)

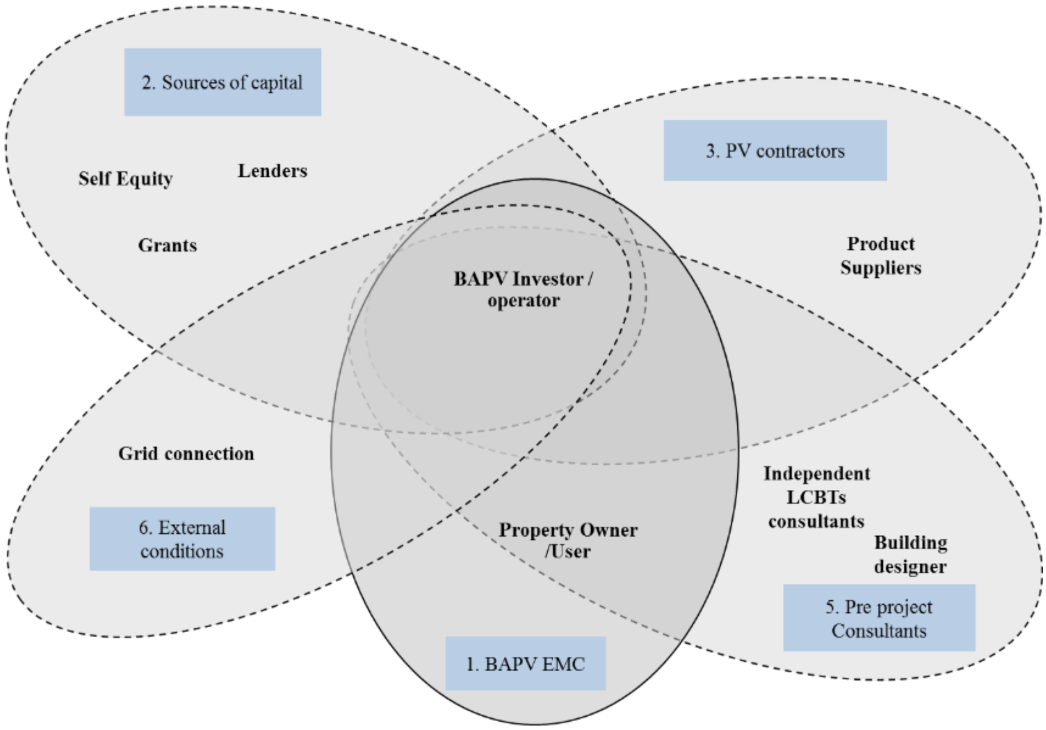
The project can bring only 100 thousand yuan benefit a year. Company A has CSR, so they did it. But it was still hard to negotiate, how to negotiate such little profit? If companies don't have social responsibilities, they won't bother doing it. (W3)

When the BIPV installation took place, the supermarket was in operation. Company A required that the power outage time must be controlled within two hours or the frozen food would have been destroyed. Company B's installation team completed the grid connection just before the prescribed time.

The power cut was set from 2AM to 4AM during the store closing time. The team sent out a text message at 3:54AM, saying "Everything is OK! We can sleep now."(W4)

Figure 7.9: CS2 BIPV grid-connection and power distribution facility (Photo by Author)

Figure 7.10: CS2 BIPV project stakeholders structure (Author's own)



The two main actors of the project are Company A (the Host) and Company B (the Investor). Other actors include independent building structure assessors, product suppliers, the Grid and Government Golden Sun. Figure 7.10 illustrates the project stakeholders' structure.

Figure 7.11: Access route to CS2 roof BIPV electricity generation (Photo by author)

Figure 7.12: Screen image of CS2 BIPV electricity generation monitoring system (Photo by author)

Motivations

Company A has ambitious sustainability goals: *to be supplied by 100% renewable energy globally* (2018 environmental statement). Company A opened more than 400 stores in China by 2016. CS2 was the only store with an on-site solar PV system installed at the time of this study. One interviewee (CS2-02) explained that Company A does not have the usage rights of the rooftop in most of its stores in China and some roofs are not suitable for PV installation. This also explains the roof ownership barrier for BIPV adoption for multi-customer buildings in China. The CS2 store building has exceptional features, making it viable for installing rooftop solar PV system. It is a single-owner individual building with large roof space. The concrete roof structure is suitable for PV installation.

In the Chinese context, Company A's low carbon energy initiatives focus on reducing energy intensity, such as LED lighting, HVAC and refrigeration systems, not including renewable energy target (2016 Global Responsibility Report).

For Company B, the motivation for investing in a BIPV project is the company's business requirement. The company is expanding its business models from BIPV EPC provider to project investor and operator.

In addition, the government Golden Sun subsidies (the scheme was discontinued in 2013) can help PV investors to achieve a good return on their investments.

7.3.2.3 Financial CSFs

The financial arrangement of CS2 shows that the BIPV adoption brings financial benefits to both the Host and the Investor. The Host saves money on its energy bills. The Investor gains revenue from the sale of electricity. Table 7.9 analyses the financial aspect of the project by using the financial CSFs developed in Chapter 6.

Table 7.9: Financial CSFs from Case study project 2

Financial CSFs	Project measures and indicators	Refined CSFs
F01-Benefits for customers	20% off discount price on solar electricity consumed by customers Save 139 tons of coal per year, about 397 tons of CO_2 emissions	**Benefit to clients** (Financial savings on small scale PV systems are not attractive for customers Carbon reduction is the main driver)
F02-Low financing cost	The sources of capital are the investor's own funds and government subsidies No interest to pay	**Low-cost financing** (This project has short payback period because of low financing cost)
F03-Acceptable investment payback level	Investment payback period < 7 years	**Attractive investment payback for investor**
F04 - Access to financing sources	Self-equity	**Appropriate financing sources available**
F05- Government subsidies	Government Golden Sun Scheme, upfront subsidies	**Good subsidies model** The Golden Sun model works on this project, but there were also approved fraudulent projects

The findings in the financial aspect show that the financial benefit of small-scale BIPV is not attractive to investors and hosts. Although it may have an acceptable rate of return, the total amount of gain/savings is small. The project participants have to do the same amount of work as the large-scale project. Investors may group a number of neighbourhood buildings with small roof space, so the total PV installation scale is large. However, there are issues when dealing with multiple owners.

7.3.2.4 Legal CSFs

For the internal legal framework, the stakeholder structure is simple. An EMC contract is adopted and the two parties also use a PV equipment lease agreement. The host party pays a monthly equipment rental fee to the investor.

PV equipment rental fee = market electricity price * 80% * amount of electricity generated from the PV system.

For the external legal framework at the time the project was carried out, only the Golden Sun Demonstration Programme and BIPV programme provided incentives to DPV projects. Government provided upfront subsidies to the approved demonstration projects to cover about 50% of the investment cost. However, the existing market conditions and policy environment are not favourable to private investors, for example, the grid were not willing to collaborate with the grid connection process, and the demand-side energy market had not opened up to private companies. Moreover, only state-owned companies can take the advantage of the supporting resources and preferential policies. This case study project became the first private retailer BIPV project in China and the first Golden Sun project by a private company, and it is the result of significant efforts and hard work made by the project parties. The success of this project also benefits the Government: the policy makers were informed about the challenges the private sector faced and improved industry regulation and legislation over time. Some barriers have been removed.

Table 7.10: Legal CSFs analysis for Case study project 2

Legal CSFs	Project measures	Refined CSFs
L01 - Credibility and transparency	Choose large, reliable partners The host party is a world leading retailer The investor is locally based qualified company	**Credibility and transparency**
L02 - Insurance mechanism	Use contract and third party guarantee Including conditional contract clause to prevent economic loss	**Insurance mechanism** (Performance or saving guarantee in EMC)
L03 - Join in government programme	Golden Sun Programme provides support, inspection, project approval and green lights to market	**Join in government programme** Golden Sun Project
L 04 - Clear defined ownership and usage rights	Project building is single owner/customer building with clear ownership The investor gains roof usage right through lease contract	**Clearly defined ownership and usage rights**
L05 - Roles and responsibilities	Roles and responsibilities are clearly defined in EMC agreement The parties have good collaborative flexible relationship particularly at the project initiating stage	**Clearly defined responsibilities**

7.3.2.5 Operational CSFs

The investor used technology innovations to improve efficiency of the operational work. The investor has in-house expertise for the whole life cycle of project development, including design, construction, operation and maintenance.

The site has a photovoltaic data acquisition and monitoring system, real-time on-site monitoring and remote monitoring of the PV system's full power and irradiance, temperature and other environmental parameters, an automatic fault alarm and power management functions.

The roof is an upright seam-type metal roof. According to this roof structure, the engineers have calculated and repeated experiments and finally determined that the aluminum alloy clamp is fixed on the rib of the roof protrusion, which is easy to install and does not penetrate the roof to damage the waterproof. (W3)

Table 7.11: Operational CSFs identified from Case study project 2

Operational CSFs	Project measures	Refined CSFs
O01 – Information disclosure for matching LCBTs and building stock	Both parties located in the same district, making it easy to gain project and company information	Information disclosure for matching LCBTs and building stock
O02 - Simplified process for project initiating stage LCBTs	The PV system investor Photovoltaic data acquisition and monitoring system, real-time on-site monitoring and remote monitoring of PV system	Simplified process for project initiating stage LCBTs
O03 - Capability of operation team	The investor is specialised in BIPV, has in-house teams for design, EPC and O&M, also established its own R&D centre	Capability of operation team
O04 - Communication and collaboration	The two parties are based in the same area, frequent communication both online and on-site	Communication and collaboration reduce risks

Operational CSFs	Project measures	Refined CSFs
O05 - Mutual benefit objectives	Project performance has impact on the interests of both parties (saving and revenue)	Mutual benefit objectives motivate collaborations
O06 - Optimise procedure	Remotely controlled monitoring system IT-integrated operation system	Optimised project procedure though technology innovations and R&D
O07 - Ensure long-term partnership	The host is an international leading company The investor has track record in it expertise	Ensure long-term partnership
O08 - Reduce operational cost	Technology innovation and remote monitoring	R&D investment to reduce operational cost
O09 - End user engagement	The host is also the end user	End user engagement

7.3.2.6 Risk allocation

The risks of the project were well managed between the investor and the host. The investor carried all financial, operational and technical risks. The host took on the risk of project approval.

Table 7.12: Risk CSFs identified from Case study project 2

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
R01 Long-term operation and maintenance risks	The host faces risks: poor performance of the system, O&M company goes bankrupt during the contract period. Choose qualified and skilled company The investor faces risks: changing tenants, the property sold to difference company.	Long-term operation and maintenance risks
R02 - Financial risks identify key	The investor faces risks:	Financial risks

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
influencing variables	non-performance on the part of host customers non-payment of the PV energy bill grid connection	Guaranteed performance contract Stable and high-energy consumer Scale up installed capacity
R03 - Better risk allocation	The investor takes on the risk of project financing, development and O&M. The host takes on the grid-connection risk and Golden Sun application	Better risk allocation
R04 - Policy risk, identify influencing factors and inform policy	This risk relies on external policies and rules This risk is high for this project. First private commercial BIPV and first private sector-led Golden Sun. No experience to follow. First time for both project parties and government authorities, time risk if a failure	Policy risk; unstable, temporary and unforeseeable policies; subsidies and implementation vary across different provinces and cities National and local policies and incentives are improved and more effective through lessons learnt from industry practises
R05 - Market risk, identify market risks for applied LCBT	Solar PV market risk The case study faces: making the solar PV project profitable and lowering operational risks and needing a more stable market	Market risk Innovations in technology and management model Innovative financing channel Reform in energy demand-side market (External enabling conditions)
R06 - Risk control measures	Grid-connection service may not be well implemented	Risk control measures See countermeasures for each risk factor above
R07 - Lack of integrity	The case study participants are reputable listed companies with lower integrity risks	Lack of integrity Trustworthy and reliable project partners

7.3.2.7 Challenges

The project faced various challenges during development. It was the first private commercial BIPV in China. The project was a Golden Sun Demonstration and required permission to operate, otherwise, it would have been illegal under the legislation and industrial rules at the time.

In addition, the project shows that a single small-scale BIPV is not suitable for a TpIP model, as it takes the same amount of preparation work as a large-scale project and it is difficult to difficult to negotiate benefit sharing with a small revenue.

7.3.2.8 Summary of case analysis

The conceptual TpIP framework was applied and tested on case study 2. The case project is a private sector-led BIPV project using an EMC third party investment model, although at that time the external regulatory and market conditions were at the initial stage. The project received support and subsidies from the external enabling Golden Sun programme and successfully initiated and operated till now. The market obstacles were relayed back to policy makers to improve the external enabling conditions for future private BIPV investments.

7.3.3 Case study 3: Rooftop PV electricity generation on building blocks in Shenzhen

7.3.3.1 Project description

Project Profile

Table 7.13: CS3 BIPV Project Profile

CS3 Rooftop PV electricity generation	
Completed year	2016
Location	CS3 Innovation Park, Shenzhen, China
Total installed capacity	0.5 MWp

Annual electricity generation	350,000 kWh/year
Type of Contract	EMC Power Purchase Agreement
Innovation	The first non-state-owned solar BIPV project under the China Golden Sun Demonstration Programme

Data collection sources

Site observation:

1. CS3 Innovation Park BIPV site (Figure 7.13)
2. Company A offices
3. Company B Solar Cloud Management Centre (Figure 7.16)
4. Company D Shenzhen office (EPC)
5. Attending project meetings as observer

Documents reviewed:

1. Building design drawings
2. Company A meeting minutes
3. Energy Management Contract Draft during negotiation
4. Tending documents BIPV Installation Design Plan,
5. Company B website
6. Project partners' website
7. Project news release

Semi-structured interviews:

1. (CS3-01) Vice President of China Merchants Development (face-to-face and online interviews)
2. (CS3-02) Manager from China Merchants Management (face-to-face and online interviews)
3. (CS3-03) Director of LCBTs R&D department at China Merchants Development (face-to-face interview)

4. (CS3-04) Company B project manager and engineer (face-to-face and online interviews)
5. (CS3-05) CEO of Company D (face-to-face and online interviews)

Case study descriptions and project participants

The CS3 rooftop PV project is located in an innovation park in Shenzhen, Guangdong Province. The Park consists of six five-storey buildings that converted from industrial plants, with a total building area of 120,000 square metres occupied by 180 enterprises and 62 shops and restaurants. Each building has a building area of about 20,000 square metres. The 0.5 MW solar power plant is installed on the rooftop of buildings No. 1, No. 2 and No. 6, covering a total area of 11,470 square metres (See Figure 7.13). The construction of the BIPV project at Building No. 2 started in June 2016 and was connected to the grid in December 2016 (Figure 7.14). The construction at buildings No.1 and No.6 started in December 2016 and was connected to the grid in June 2017. According to the data provided by Company A, the average annual energy generated from this solar power plant is equivalent to saving 137.8 tons of standard coal, reducing 2,344.4 tons of CO_2 emission, 13.2 tons of sulphur oxides and 6.6 tons of nitrogen oxides. The researcher made several visits to the site between 2014 and 2016. The last visit took place in the construction stage in 2016. Figure 7.14 shows the image of the construction site on the roof of building No.2 during researcher's field study in 2016.

CS3 Innovation Park is owned and was retrofitted by Company A. It is managed by Company C (a property management company), a subsidiary of Company A. Company A is also the main urban developer and operator of the local district where this project located. The district is under a new wave of urban upgrading regeneration, transforming from an old industrial zone into a commercial and residential mixed-use urban area. The CS3 innovation park is the first example of converting old industrial plants into modern green office buildings in this area (see Figure 7.15). Building No. 3 is Company A's headquarters. The other five buildings are operated as serviced office spaces and are leased out to SME businesses. The CS3 office buildings are designed to be highly energy-efficient buildings. The development has adopted more than 12 low carbon building technologies and achieved a two-thirds energy reduction compared with the same standard office building in Shenzhen. Company A integrated a BIPV system with 38 kW capacity into the first completed retrofit building (No. 3) and encountered four obstacles in their self-funded adoption: *cost too high, payback period too long, difficulty connecting to the grid and low photoelectric conversion efficiency* (Company A, 2010). The other five buildings did not install a PV system at the time of the retrofit construction in 2011. Since Chinese central government is vigorously promoting DPVG, more and more building projects have adopted BIPV in China. Company A started to consider installing a solar PV system on the other buildings of the innovation park and decided to use a third party investment model to implement this. In 2016, Company A signed an EMC agreement with Company B to carry out the CS3 BIPV project.

Figure 7.13: Map of CS3 Innovation Park and the BIPV installations on Buildings 1, 2 & 6 (Map created from Google map)

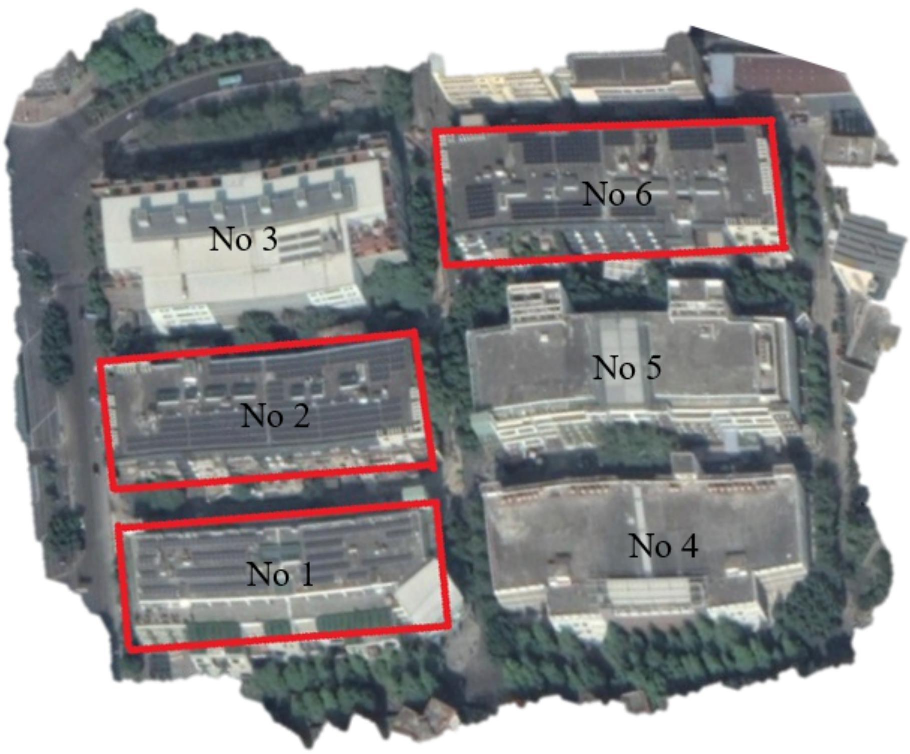


Figure 7.14: CS3 No. 2 building rooftop PV project construction site (Photo by author)

Figure 7.15: CS3 building retrofit before and after images (provided by Company A)

In the EMC agreement, Company B was responsible for the investment, construction and operation of the BIPV project on buildings 1, 2 & 6. Company B is a fast-growing Chinese solar power plant investor and operator headquartered in Hong Kong. The Company builds and acquires solar power projects throughout the country and some overseas regions. As of the first quarter of 2017, the company owned 38 solar power plants with a total capacity of approximately 1.4 GW. Company B won the national "Top Runner" project in 2017.

In 2013, Company B initiated a platform on which a number of state-owned enterprises and listed companies in the solar PV industry signed a strategic cooperation framework agreement to work in partnership on PV power projects. The partnership brings different parties together, including investors, developers, constructors, operation and maintenance providers and suppliers, to create a financial and business platform. Partnering companies collaborate in all aspects of PV power applications, including technology research, project development, investment, construction, management, operation and maintenance services, and sharing benefits of the collaboration projects. The CS3 rooftop PV power plant is the first BIPV collaboration project of this platform (source: Company B's official website).

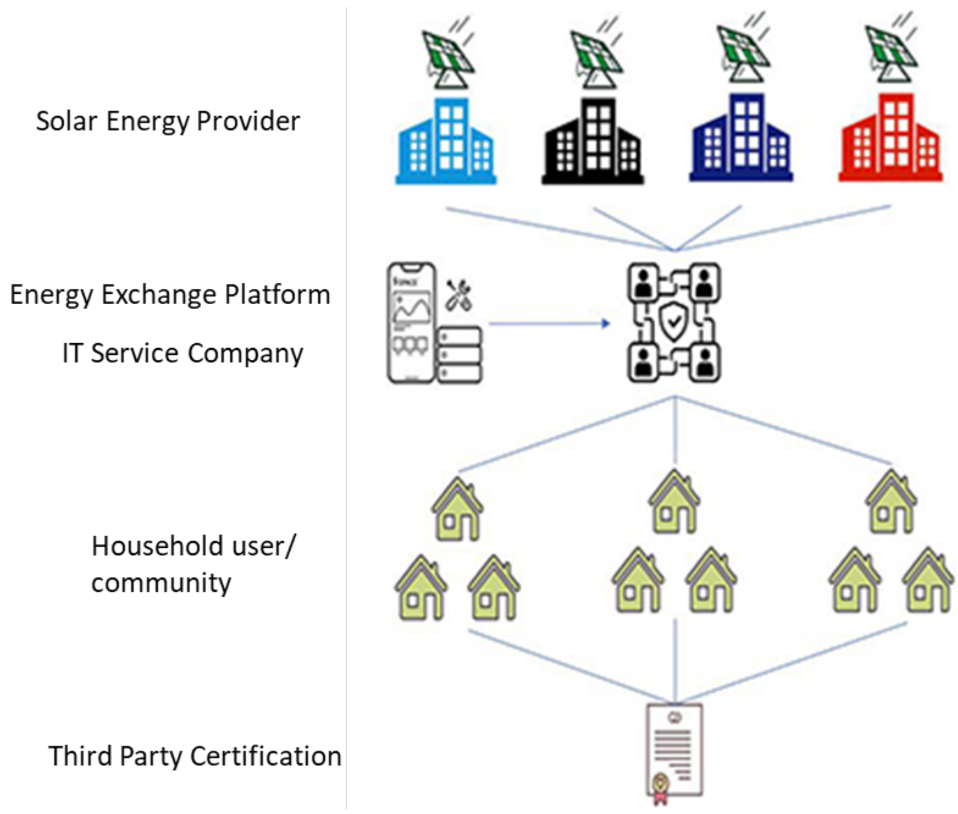
The project works in partnership with a leading IT company integrating Internet technologies with energy management. It developed a Smart PV Cloud Management Centre to provide comprehensive management from four perspectives including production management, human resources management, assets management and data management. The technology helps increase the total volume of power generation while lowering the costs of operation, thus enhancing the efficiencies of power generation management and operation. Figure 7.16 is the Solar Cloud Management Centre at Company B. The system shows real-time data of different power generation plants.

Figure 7.16: The Solar Cloud Management Centre at Company B (Photo by author)

The project also developed an energy Internet platform, where the household users can apply to claim the solar electricity generated by the CS3 BIPV plants. 100 households from local communities participated in the pilot project. The users can access the platform through a login on the website or a mobile phone application to view the real-time generation data and claim the remaining solar PV electricity. The built-in smart contract will pair the user with the PV power plant directly and a third party certificate will authenticate the process and issue an electronic certificate to prove that the user has claimed the green solar energy. The solutions aim to set up a platform for global energy transaction by leveraging blockchain technology so as to bring affordable, reliable and sustainable new energy to thousands of households. Figure 7.17

demonstrates that the energy blockchain application of CS3 is built upon cross-sector collaboration (Company B's document and mobile app).

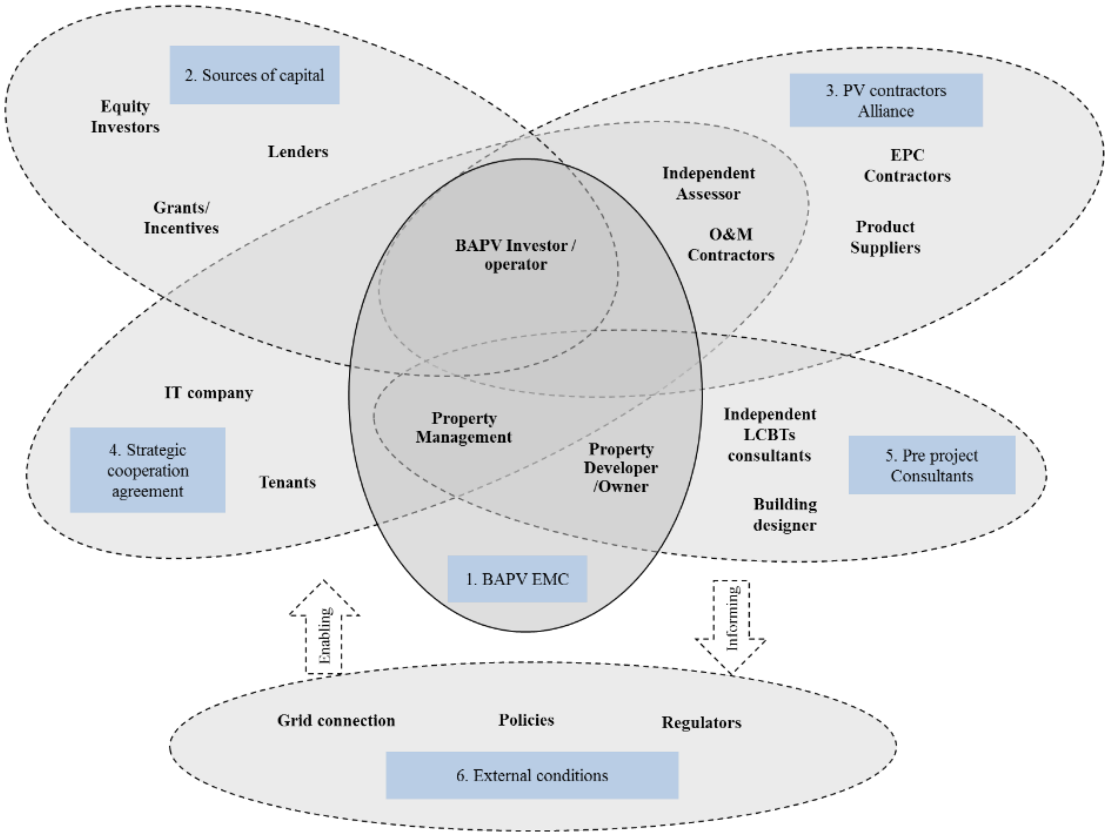
Figure 7.17: Energy Blockchain Application (Source: Company B)



7.3.3.2 Stakeholder relationship

Stakeholders structure

Figure 7.18: CS3 BIPV project stakeholders structure (Author's own)



Motivations

Table 7.14: Motivations for CS3 PV Project Participants

Project Participants	Motivations	Roles & responsibilities
Property Developer/Owner	Leadership in green building	Providing roof space
Property Management	Service upgrading Saving money	PV electricity buyer and consumer

Project Investor and operator	Business Investment return	Invest in, install, operate and maintain the BIPV system
BIPV Partnership Contractors	Business Long-term partnership	Providing services for all aspects of PV supply chin
Third party certifier	Business Long-term partnership	Providing PV system assessment and issue green power certificate
IT technologies	Business Cross-sector application	Technical support on O&M system Internet+ energy R&D and application
Source of Capital	Financial return Requirement for policy bank	Providing investment capital funds
Tenants	Environmental protection awareness	Voluntary purchase green power

7.3.3.3 Financial CSFs

The COMPANY B used equity crowd-funding in cooperation with its two strategic partners through China's Internet crowdfunding platform that raises capital from the public to develop a megawatt-level BIPV project in south China, (COMPANY B, 2017). However, according to a report in The Diplomat, Liu Zhangjun at the China Banking Regulatory Commission remarked that crowdfunding and peer-to-peer lending were potentially illegal and should be paid particular attention (The Diplomat, 2017).

Table 7.15: Financial CSFs for Case study project 3

Financial CSFs	Project measures and indicators	Refined CSFs
F01 - Benefits for customers	15% discount on market price	**Saving to clients**
F02 - Low financing cost	Financing sources are from outside of mainland China, relative lower cost	**Low cost financing** (currently, only state-owned companies and large companies are able to get below market benchmark rate)
F03 - Acceptable investment payback level	IRR=9>8%, ROI=7-9 years	**Attractive investment payback**
F04 - Access to financing sources	Equity investors, bank loans, crowdfunding, subsidies	**Appropriate financing sources available** **Availability of bank loan financing** (Long-term income to pay short-term loan) (Crowdfunding still has legal issues in China)
F05 - Government subsidies	The project works in partnership with the local government	**Government partnership**
Other CSF	Guaranteed minimum consumption	**Stable cash flow** (predictable and stable)
Other CSF	Crowdfunding and peer-to-peer lending were potentially illegal	**Good subsidies model** (Good subsidies model can encourage high quality and efficient products, foster competitive and healthy market, aim for energy parity without subsidies)

7.3.3.4 Legal CSFs

The internal framework includes contracts and agreements between project parties, such as the EMC. The external legal framework includes project enabling laws, regulations, policies, permissions and inspections.

The case project established internal agreements and partnerships for the innovation model the investor applied, which includes an ENC PPA, crowdfunding, blockchain energy platform and supply chain partnerships.

External legalisation support of the case study includes: Government No. 9 Notice, PGO, special economic zone policy, government Internet advice.

Table 7.16: Legal CSFs for Case study project 3

Legal CSFs	Project measures	Refined CSFs
L01 - Credential system	Group subsidiaries and industrial alliance, cross-sector partnership	Establish industrial alliance working in partnership
L02 - Insurance mechanism	Leaders in specialised field ensure high quality and professionals Including conditional contract clause to prevent economic loss	High-standard and quality performance, third party certification and assessment
L03 - Government policy	New energy market reform Internal and external interaction informs and supports	Working in partnership with the local government Mutual objectives
L04 - Clearly defined ownership	Single-owner in multi-customer building, common management, lease contract	Clearly defined ownership and usage right
L05 - Roles and responsibilities	Defined in EMC agreement and other commissions contracts	Clearly defined responsibilities
Other CSFs	Give innovation Internet + application opportunity to grow with government inspection	Internet law

7.3.3.5 Operational CSFs

Project process and management analysis

Figure 7.19 demonstrates process stages of the BIPV development.

Figure 7.19: CS3 BIPV Project Process Stages (Author's own)

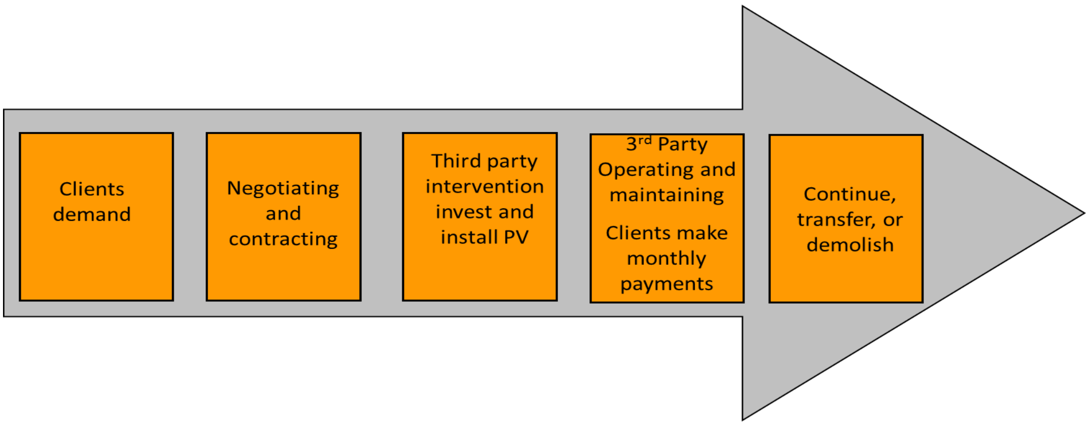


Table 7.17: Operational CSFs for Case study project 3

Operational CSFs	Project measures	Refined CSFs
O01 – Information disclosure for matching LCBTs and building stocks	All parties are industry leaders and are members of local industrial alliance	Information disclosure for matching LCBTs and building stocks
O02 - Simplified process for project initiating stage LCBTs	Centrally controlled system with end user app Simplified process reduces labour	Simplified process for whole project life cycle
O03 - Capability of operation team	Each task allocated to professional team. The investor works in partnership with leading companies in BIPV design EPC O&M and ICT, also established its own R&D centre	Capability of operation team

Operational CSFs	Project measures	Refined CSFs
O04 - Communication and collaboration	Smooth and transparent communications, collaboration on mutual objectives	Communication and collaboration increase efficiency and reduce risk
O05- Mutual benefit objectives	Members of the industry alliance	Mutual benefit objectives motivate collaborations
O06 - Optimise procedure	Centrally controlled monitoring system, big data technology ICT integrated operation system	Optimise project procedure though technology innovations and R&D
O07 - Ensure long-term partnership	Established alliance, all parties signed common goal agreement	Ensure long-term partnership
O08 - Reduce operational cost	Central management and remote monitoring Internet+ Energy innovation: FusionSolar system and Energy Blockchain application	R&D investment to reduce operational cost
O09 - End user engagement	Blockchain application	End user engagement

7.3.3.6 Risk allocation

This case project integrated Internet technologies into their operation and management system. The project also used blockchain energy to engage with local community. However, there are great concerns about Internet risk in China and in some cases risks are not managed well. SPI's Solarbao model is a crowdfunding example in China. It has a high rate of return - around 10% for an Internet investor. There is a need to improve the regulation of solar PV Internet financing, which provides an excellent channel for the public to make indirect investment in solar PV projects. Currently, internet financing operates with unclear legal boundaries in China.

Table 7.18: Risk CSFs for Case study project 3

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
R01 Long-term operation and maintenance risks	The host faces risks: poor performance of the system, O&M company goes bankrupt during the contract period. Choose qualified and skilled company The investor faces risks: changing tenants, the property sold to difference company.	Long-term operation and maintenance risks
R02 - Financial risks identify key influencing variables	The investor faces risks: non-performance on the part of host customers non-payment of the PV energy bill grid connection	Financial risks Guaranteed performance contract Stable and high-energy consumer Scale up installed capacity
R03 - Better risk allocation	The investor takes on the risk of project financing, development and O&M The host takes on grid-connection risk and Golden Sun application	Better risk allocation
R04 - Policy risk, identify influence factors and inform policy	This risk relies on external policies and rules This risk is high for this project. First private commercial BIPV and first private sector-led Golden Sun. No experience to follow First time for both project parties and government	Policy risk; unstable, temporary and unforeseeable policies; subsidies and implementation vary across different provinces and cities National and local policies and incentives are improved and more effective through lessons

Risk CSFs	Risk allocation	Refined CSFs and countermeasures
	authorities, time risk if a failure	learnt from industry practises
R05 - Market risk, identify market risks for applied LCBT	Solar PV market risk The case study faces: making the solar PV project profitable and lowering operational risks and needing a more stable market	Market risk Innovations in technology and management model Innovative financing channel Reform in energy demand-side market (External enabling conditions)
R06 - Risk control measures	Grid-connection service may not be well implemented	Risk control measures See countermeasures for each risk factor above
R07 - Lack of integrity	The case study participants are reputable listed companies with lower integrity risks	Lack of integrity Trustworthy and reliable project partners

7.3.3.7 Innovations

Global Smart PV Cloud Management Centre - FusionSolar system

Following the national strategy of ‘Internet+’, the Global Smart PV Cloud Management Centre (abbr. Cloud Management Centre) integrates Internet technologies with energy management and was developed in partnership with a leading company in Internet technologies. The Cloud Management Centre achieves centralized management of the group’s plants, helping to realise comprehensive management from four perspectives, including production management, human resources management, assets management and data management. This Cloud Management Centre enhances the efficiency of management, operation and maintenance, increasing the total power generation volume while lowering costs for the group.

The Cloud Management Centre, through the O&M Analysis System and centralized deployment of experts, helps the group to achieve three transformations solar power plant operation and management in the Internet era (i.e. from passive to active, from spot to distant and from extensive to fine management).

7.3.3.8 Summary of case analysis

The project investor/operator uses the most advanced technologies to centrally manage and to link the BIPV project with other PV projects. The investor established a PV industrial alliance, bringing the leading companies in their own field to collaborate on a number of projects including this case project. All parties are, therefore, deeply engaged in the project and input their best expertise to bring the project to the highest standard. The operation and performance data will be shared among project participants. The project also adopted an EMC model. The industrial alliance acts as one entity, taking the role of project investor, with the local utility as the electricity buyer and the property management company acting on behalf of the building owner, leasing out the roof space to the investor for system installation. In the next section, the TpIP framework is developed with detailed explanations through cross-case analysis.

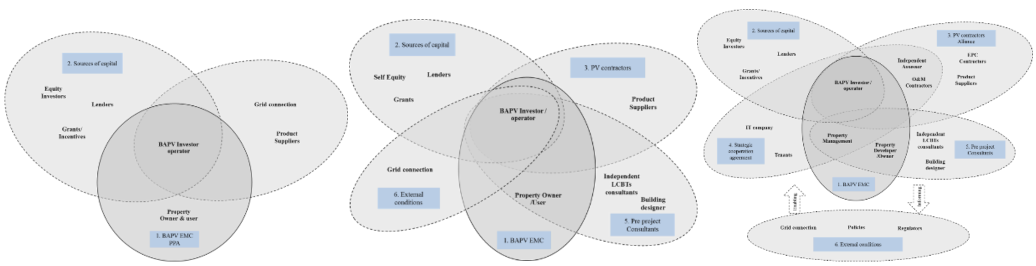
7.4 Cross-case analysis and developing TpIP framework

Deep analysis for each case study has been described in the previous sections. This section combines the findings of the three case studies and develops a detailed TpIP framework for BIPV projects in China with case study triangulation. Cross-case findings on FLORE aspects are described in the following sections and the detailed cross-case analysis can be found in Appendix L of this thesis.

7.4.1 Analysis stakeholders relationships, actors and business model of BIPV projects

This study investigated the actors of three case study projects against the stakeholders' structure (see Figure 6.4) developed through the expert forum. The participants of the three case studies cover a wide range of sectors, such as low carbon building technology consultancy, PV industry third party services, ICT company, investment and financing bodies, and utility. Various relationships are formed in the case projects (see Figure 7.7, Figure 7.10 and Figure 7.18), presenting an organically developed pattern of structure. Comparing these figures together (see Figure 7.20), it shows that all actors and relationships within the projects are linked by BIPV EMC business, which is the third party investment model applied to three case studies. Within these structures, the participants and their related services and activities can be divided into two side of forces: BIPV energy production and solar PV energy market. They were mostly separated businesses out there in the markets before the BIPV EMC business brought them together to work on the BIPV case projects. The actors adjusted their roles and responsibilities to meet the business and project requirements. They grow organically to form a bigger partnership and make better performance for the BIPV projects. In other word, TpIP framework of BIPV project is that the EMC third party investment business bring BIPV energy production forces and solar PV energy market forces together, to make a business driven and benefit sharing model for BIPV installation and operation. In the case projects, each participant is either responsible for one actor's role or undertaking multiple actors' roles, depending on their business areas, in a bid to minimize their overheads and maximize their profit margin.

Figure 7.20: Cross case study stakeholders' relationship model



CS1 *CS2* *CS3*

Table 7.19: TpIP actors for BIPV case study projects in south China

Forces	Actors	Participants in 3 case projects	CS1	CS2	CS3
PV electricity production	**Host**	Property developer and management			√
		Property owner and user	√	√	
	Investor	BIPV developer	√	√	
		Energy Company			√
	Sub-contractor	EPC			√
		IT company			√
	Capital source	Self-fund	√	√	
		Equity investor	√		√
PV electricity market	**Independent service**	PV assessor			√
		Designer and consultant			√
	Government	State grid	√	√	√
		Incentives	√	√	

Table 7.19 shows that TpIP actors are classified into PV electricity production and PV energy market, the EMC BIPV business acts as agent joining the two groups together. The stakeholders' structure is re-organised, helping to improve the flexibility to suit the complexity of stakeholder relationships and to clarify the drivers to the variety of participants, thus encouraging the adoption of BIPV.

7.4.1.1 The BIPV EMC business

All three case studies adopted an innovative EMC business model to install rooftop solar power plants on buildings. The BIPV investors take over the financial, operational and technical responsibilities from the project hosts while charging them fees for selling PV electricity as well as satisfying their CSR needs. The advantage of this model is that it fully uses the professional ability of PV power plant developers, reducing the transaction cost of project investment and generating a higher income. The performance of EMC for BIPV project in China is discussed in Chapter 4 (see section 4.2.2 and 4.2.3).

7.4.1.2 The rooftop solar PV electricity production

The rooftop solar PV electricity production includes a range of forces and actors as shown in the three case studies. Based upon the complexity of projects, this requires a flexible arrangement of roles, responsibilities and risk transfer. Table 7.19 shows a great deal of diversity of participants in the three case study projects. With the TpIP, the actor categories were identified through the expert forum process. It revealed that some actors may be combined in one participant. For example, the BIPV developer in CS1 took on multiple roles including design, construction, operation and management of the rooftop solar power plant, which also required it to act as sub-contractor and independent services. Whereas, the energy company in CS3 only acted as the investor, they sub-contracted other professional services to third parties.

7.4.1.3 The solar PV energy market

While adopting a TpIP EMC business model and financing mechanisms for BIPV, investors need to consider which market segment is suitable for BIPV investment. This study identified the following factors for BIPV EMC market choices:

Building types

Large industrial and commercial buildings, which provide large roof space for solar panel installation. The electricity price is higher than the grid sale price, hence, a higher investment return.

Costumer segments

Large reputable enterprises consume more and stable electricity, and their credibility reduces the risks of non-payment. All three case study buildings are single owner type. They are owned and managed by owners. CS1 & CS2 are owner-occupied and self-management. The CS3 building is self-developed and managed by the owner. The building is leased to multiple tenants who pay rent and utility bills to the management company. Under single ownership and self-management building types, the investor only needs to negotiate with one party - the owner. This simplified contract process reduces the risk of uncertainty and the cost of negotiation.

7.4.2 Drivers for TpIP actors in BIPV case study

As discussed above, TpIP actors are divided into two forces: PV electricity production and PV electricity market. This section discuss the question: Do TpIP motivate actors to participate in BIPV production and market? Table 7.20 shows the motivations of actors in three case study projects.

Investment and business opportunities are main motivations for investors and service providers. Government incentives are also key drivers for investors, as they provide investment conditions and open up the market to the private sector. CSR is a key driver for demand side actors. All three host companies have raised the issue of minimizing carbon emissions up the corporate environmental agenda. Additionally, the Chinese government's support for PV deployment and the rapid growth of the PV industry positively influenced the three case projects. Other motivations include business opportunities in the growing PV industry, providing demands for third party services, such as assessment, insurance and financing. The case studies reveal that an owner's awareness is not a strong driver for decision making. Higher sale value and regulatory compliance drivers identified in the expert forum process are not applicable for the chosen case study buildings.

Table 7.20: Drivers for adopting TpIP model on BIPV project in China

Types	Forces for adopting TpIP model for BIPV project in China	CS1	CS2	CS3
PV electricity Production	**1. Save money for adopter**	√	√	√
	2. Investment opportunity	√	√	√
	3. Self-requirement	√	√	√
	4. Government incentives	√	√	√
PV electricity Market	**5. Business opportunity for independent services**	√	√	√
	6. PV industry development	√	√	√
	7. Political pressure for government	√	√	√

7.4.3 Overcoming Barriers by TpIP model for BIPV project

This section examines if the TpIP model in the case study project helped with overcoming barriers of BIPV deployment in China. The case studies discovered that

TpIP internal measures can only overcome certain barriers identified for BIPV deployment, such as extra cost and high risk for the host. Some of the barriers need external support measures to eliminate them, for instance, uncertainty of political will, low profitability, conflict of interests between stakeholders, lack of market integrity and long payback period. The other barriers can be overcome through market choice, for example, the choice of single ownership type buildings to eliminate complicated ownership structures. Table 7.21 shows how and to what extent the different group of measures within the TpIP framework help to overcome the barriers identified from the expert forum in this study. One tick is shown if a group of measures can partially help and two ticks represent when the corresponding group measures can provide significant help in overcoming the barrier. Where no tick is shown, the measures cannot help to overcome that barrier.

Table 7.21: Barriers removed by TpIP model for BIPV project

Barriers identified for BIPV project in China	Barriers removed by PV production forces	Barriers removed by PV energy market forces	Barriers removed by third party EMC business
Skills and knowledge barriers	√√		√√
Uncertainty of political will		√√	
Weak market demand		√	√
Lack of market support		√	√
Extra costs			√√
High capital cost		√	√√
Low profitability	√	√	√
Conflict interests between stakeholders		√	√
Complicated ownership structures		√√	
State-owned companies dominate market		√√	
High financial risk	√	√	√
Lagging laws and regulations		√√	
Lack of financing sources		√	√√
Low carbon benefit not obvious			√√
Lack of market integrity		√√	
Long payback period		√	√

7.4.4 Evaluation of the CSFs in case study BIPV projects

The study applied a FLORE framework to evaluate CSFs identified in the previous research stage. Measures and indicators are revealed against each CSF in the three case study projects. A detailed FLORE model evaluation is described in the following sections.

7.4.4.1 Financial aspect

Benefits for customers - The project hosts of all three case studies were initially driven by the company's carbon reduction or green branding requirement. Financial savings were less attractive for them but were an essential factor for making decisions.

Low financing cost - The findings show that low financing costs contributed to the success of the three case studies. The investors in all three case studies were state-owned companies and public listed companies who were able to get below the market benchmark rate. However, SMEs' financing costs are normally very high in China and they are not competitive in the market.

Acceptable investment payback level - All three case studies had an attractive investment payback rate and were all above the average baseline of investment decision (IRR>8%, Payback period<7 years). This was the key driver for investment.

Access to financing sources - Current financing methods are limited and not suitable for long-term payback investment. The investor of CS1 expressed they had cash flow pressure, preventing the company from expanding their business. More flexible financing sources should be available to meet different needs. There is a high liquidity risk when a company uses long-term returns to cover short-term loans. The investor of CS3 used crowdfunding for another BIPV project, but crowdfunding still has legal issues in China.

Good government subsidies model - All three case studies expressed that the availability of government subsidies is a critical factor to ensure a project makes a profit, however, investors have to make efforts to reduce cost and increase efficiency to be able to compete in the market. A good subsidies model can encourage high quality efficiency products, foster a competitive and healthy market and aim for energy parity without subsidies.

Predictable and stable cash flow is included on the list of financial CSFs in the three case studies and a guaranteed minimum consumption measure is adopted to ensure this factor.

5.4.4.2 Legal aspect

The refined legal CSFs and measures are as follows:

Credibility and transparency - All project partners in the three case studies showed good credibility and transparency, and they are all public listed companies. The sub-contractors of the project were also leaders in their own professional fields.

Insurance mechanism – Operation performance guarantee in EMC, and product specification risk was contracted out to product supplier.

Benefit from participation in government programme – Two of the case studies were local demonstration projects, one case study was a national programme.

Clearly defined ownership and usage rights – The three case study projects were single owner buildings. The property ownerships were clear. The investor could obtain usage rights of the roof space through a lease agreement.

Clearly defined responsibilities – The roles and responsibilities were clearly defined in the three case projects. In case 1 and case 2, the investors took full responsibility for the project for finance, installation and O&M. while the investor in case 3 contracted out to EPC.

Flexibility and innovative contracts - Despite all three case studies using an EMC agreement for BIPV development, the case studies analysis also shows how these legal arrangements were also characteristically different in contract structure and financial arrangement. For example, CS1 and CS2 used a host-investor two-party agreement and CS3 used a host-investor-utility three-party agreement. In CS1 & 2, the PV electricity was sold directly to the host. While in CS3, the electricity was sold to the utility company and rent was paid to the host for using the roof space. Another important characteristic difference is the resources each project investor had. CS1 and CS2 had relatively few financial resources available to them, whilst investor of CS3 had sufficient funds and the company worked in partnership with all resource providers. These characteristic differences meant that the TpIP legal framework needed to be flexible and innovative to suit different requirements.

Internet law – This is a legal issue for internet financing and internet + energy model emerging in China. Case 3 is integrated with these technologies. New laws should be in place to regulate the market and to maintain a safe and healthy environment.

7.4.4.3 Operational aspect

The investors of the three case projects have different strengths in their expertise and their ability to arrange and deploy resources. There are both similarities and differences in their operational procedures. The findings for the operational CSFs and measures are as follows:

Information disclosure for matching LCBTs and building stocks – Assessments of this factor in the three case projects showed a good level of information disclosure. Partners in the three case projects were public listed companies, while parties in case 3 were related companies. Investors in CS1 & CS2 had a location advantage to the projects, and there was also an internet platform for project tendering announcements.

Simplified process for project initiating stage LCBTs - A simplified process reduces time and labour costs before a project is initiated, increasing the chances of gaining projects and shortening the project cycle. Cross-case analysis shows that this factor contributes to the success of a project.

Capability of operation team – Analysis shows the operator of the three case projects had a highly skilled operation team, critical to the success of projects. The investment revenue relies on the output of the system and operation cost. Lower operation cost gives the investor more flexibility in negotiation, hence, this increases the competitiveness of the company.

Communication and collaboration – The cross-case study shows that smooth communication and collaboration between project partners throughout project development and operation are essential to the success of a project. CS2 gives good supporting evidence (see section 7.4.2.2) that without the collaborative relationship, CS2 would not have happened. CS1 and CS3 also proved this point. In addition, analysis of the case project indicates this factor reduces operational risks and running costs.

Mutual benefit objectives motivate collaborations – The collaborative partnerships of the CS3 stakeholders model (Section 7.4.3.2, Figure 7.18) encouraged participants to engage in project operation and innovations.

Optimise project procedure – All three case projects had the common feature of optimised operation and management by applying innovative technologies. The investors had a high proportion of investment in R&D.

Secured long-term partnership – The investment in BIPV relied on long-term return and a long-term partnership ensured the continuation of the project. The agreement of the case project was 20-25 years.

Reduce operational cost - Standard and replicable procedures reduce operational cost and enable scale-up, as proven by these case projects. BIPV investors need to grow business by scale-up. Standard procedure reduces management cost. The operation system is centrally controlled, the management team can monitor all solar PV projects running in any locations (Section 7.4.3.1, Figure 7.16). This has become the standard system for large PV operators in China.

End user engagement – In these cases, the host is also the end user.

7.4.4.4 Risk aspect

The finding summary of risk CSFs and measures are as follows:

Long term O&M risks - The investors/operators of the case projects were specialists in the design, building, operation and maintenance of the BIPV systems, guaranteeing the performance of these systems.

Financial risks - The case projects investors had the advantage of raising low-cost capital for the upfront costs of the BIPV project through choices of financial sources, i.e. their own capital or borrowing from financial institutions, such as a bank. Thus, financial risk was transferred away from the project hosts, safeguarding them from the financial risk. They were also guaranteed energy cost savings by paying a discount price for consuming solar energy. Meanwhile, they took over building performance risk, guaranteeing minimum energy consumption.

Better risk allocation – The investor took on the project financing, development and O&M risks. The host took on the building performance risk. The product suppliers took on products performance risk.

Policy risk – The case projects joined national and local government programmes, receiving long-term support, as well as working with government in partnership.

PV market risks – a BIPV TpIP agreement is normally financially viable for medium to large-sized businesses, rather than smaller businesses, because they have larger production costs. This is because although a TpIP agreement may provide a large percentage reduction in the production costs of smaller organisations, these absolute savings are likely to be outweighed by the associated transaction costs.

Risk control measures – Technology innovations, such as BIM and smart systems, apply for operation and management. Grid-connection service is guaranteed.

Lack of Integrity – BIPV project participants engage in long-term contracts typically lasting between 20 to 25 years. Measures include using public listed companies and reliable project partners.

7.4.4.5 External Enabling Conditions

In this section, the cross-case analysis studies all three case projects and the external enabling environments as a whole, analysing the relationships between them. The three case projects were built in different years from 2011 to 2016. During this period, the policy and market environment changed dramatically, as did rapid growth of domestic DPV installation in China (see Section 4.2 in Chapter 4). Each case study is a typical example of private-led BIPV development in its build time. Fig

In this interaction pattern, the external support measures provide enabling conditions for BIPV commercial projects to realise. BIPV projects inform policy makers about practical barriers and risks, the external support measures increase accordingly, more commercial BIPV projects are built and so the external support measures continue to improve. The evolution of BIPV investments and external enabling conditions indicate that BIPV investment in China is not a purely “top-down” market. Bottom-up influence also drives industry growth. The private sector has started to take some level of lead and it has shown an increasing trend. Before a mature market can be established, the external enabling conditions continue to provide CSFs to BIPV investments. To this end, according the cross-case FLOR analysis in this section, the CSFs of external enabling conditions and measures are identified as follows:

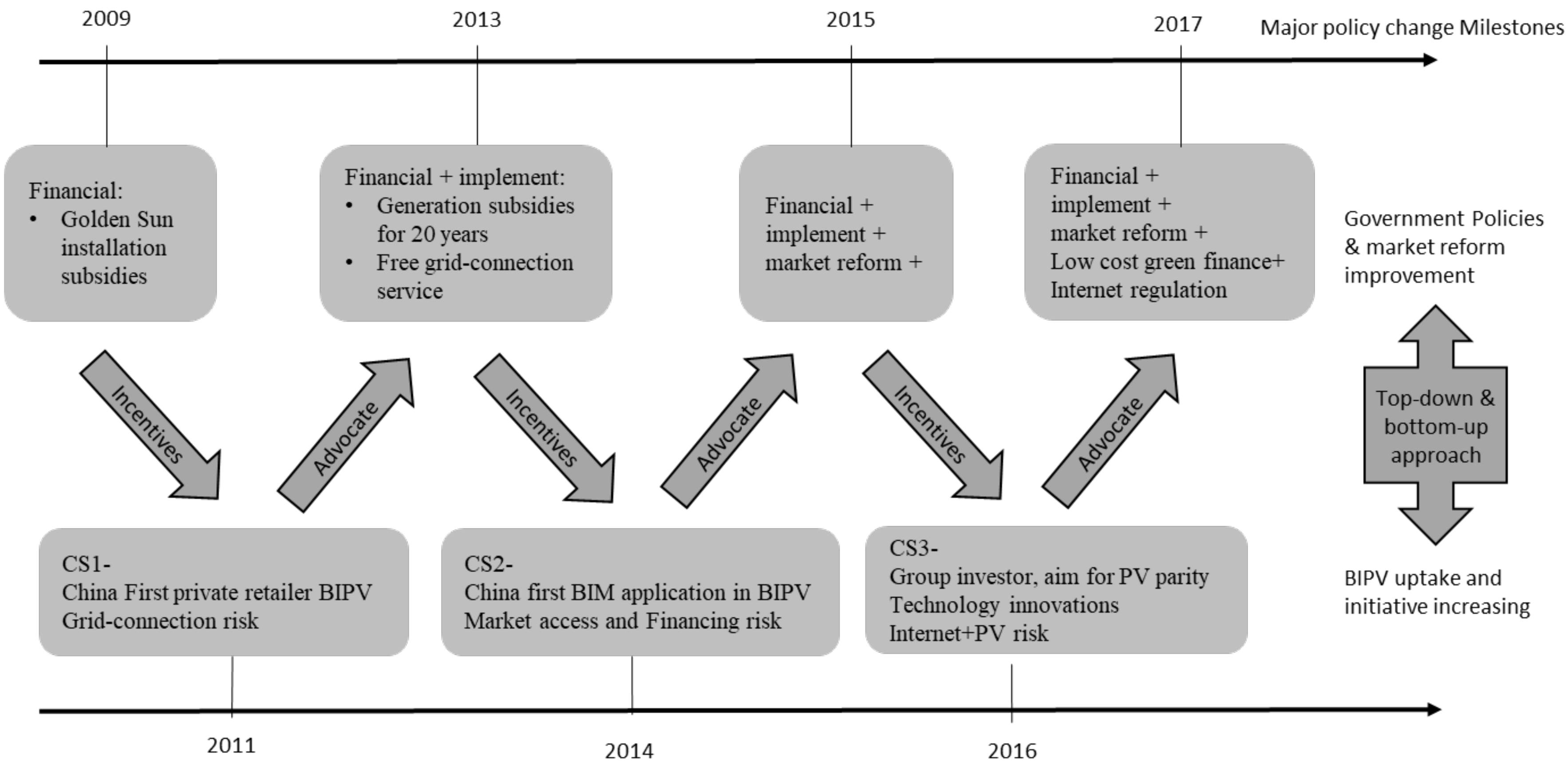
- **"Carrot, stick and trumpeter" policy** - Credit information platform,
- **Reform constrained market** - Reform in energy demand-side market and energy retail market. Financial, implementation, and Internet+PV regulation
- **Government incentives** - Golden Sun Scheme and PV electricity FiT subsidies
- **Government commitments and national targets** - Reach retail parity, no need of subsidies in future.

Figure 7.21 below represents the three case study projects and the external enabling conditions, in chronological order. It presents a pattern of interaction and evolution between BIPV uptakes and policy & market reform over the years.

In this interaction pattern, the external support measures provide enabling conditions for BIPV commercial projects to realise. BIPV projects inform policy makers about practical barriers and risks, the external support measures increase accordingly, more commercial BIPV projects are built and so the external support measures continue to improve. The evolution of BIPV investments and external enabling conditions indicate that BIPV investment in China is not a purely "top-down" market. Bottom-up influence also drives industry growth. The private sector has started to take some level of lead and it has shown an increasing trend. Before a mature market can be established, the external enabling conditions continue to provide CSFs to BIPV investments. To this end, according the cross-case FLOR analysis in this section, the CSFs of external enabling conditions and measures are identified as follows:

- **"Carrot, stick and trumpeter" policy** - Credit information platform,
- **Reform constrained market** - Reform in energy demand-side market and energy retail market. Financial, implementation, and Internet+PV regulation
- **Government incentives** - Golden Sun Scheme and PV electricity FiT subsidies
- **Government commitments and national targets** - Reach retail parity, no need of subsidies in future.

Figure 7.21: Interaction and Evolution BIPV Case Studies and External Enabling Conditions (Author's own)

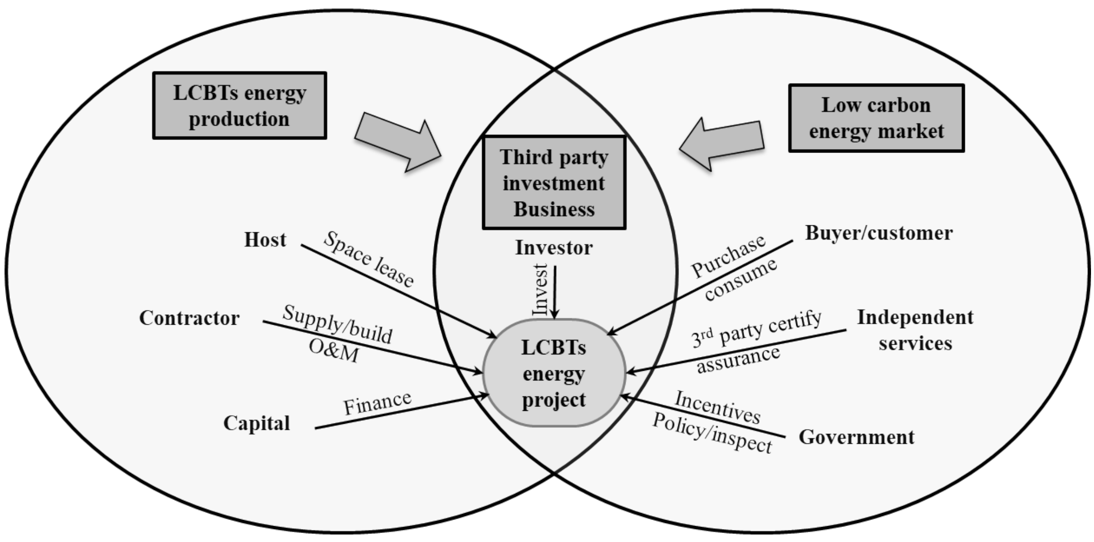


7.5 Refined TpIP Framework

7.5.1 Third Party Investment Partnership (TpIP)

Triangulation of the case studies findings revealed a more complex picture of TpIP, which provides a deeper understanding and rich evidence of what a TpIP means and how it performs in practice through case study BIPV projects in China. The refined TpIP is not just about stakeholder's relationships as previously defined through the expert forum (Section 6.4.1 in Chapter 6), but is an holistic partnership model that brings different forces together with a range of stakeholders to create a collaboration mechanism through benefit sharing business. The case study findings show that there are different forces at play within the partnership, which are divided into two sides. One side is *Low Carbon Building Technologies (LCBTs) Energy Production*, which brings forces and actors together to produce low carbon electricity from buildings. The other side is the *Low Carbon Energy Market*, which consists of forces and actors being combined to create consumer markets for low carbon energy. At the core of the TpIP is the *Third Party Business*, which acts as an agent to bring the two sides together to make the partnership work. **Error! Reference source not found.** illustrates the refined TpIP framework derived from this study. Within this TpIP framework, two forces, *LCBTs Energy Production* and *Low Carbon Energy Market*, are brought together by an agency, which is the *Third Party Business*.

Figure 7.22: Refined TpIP framework (Author's own)



7.5.2 The Third Party Business

The core of TpIP is the *Third Party Business* where a third party invests in the *Low Carbon Energy Market* in order to make a profit through investing in LCBTs on the host's building and selling low carbon energy generated from the LCBTs to customers. Therefore, the business acts in an agency and investment role to bring together different forces and actors to form a mutually beneficial or symbiotic partnership. For instance, in the case study projects, the BIPV EMC business combines forces from BIPV electricity generation and the solar PV consumer-side market together to create and deliver a viable and profitable BIPV investment (see Section 7.5.1.3 in Chapter 7).

7.5.3 LCBTs Energy Production

Buildings can produce low carbon energy by integrating low carbon energy technologies. *LCBTs Energy Production* consists of forces and actors that are required for the input of LCBTs construction and energy production. The actors, such as host, contractors and sources of capital, are the main players within the production forces. The cross-case study analysis in this chapter reveals the participating actors and driving forces on the production side in the rooftop solar PV power generation projects in China (see Section 7.5.1.1 of Chapter 7).

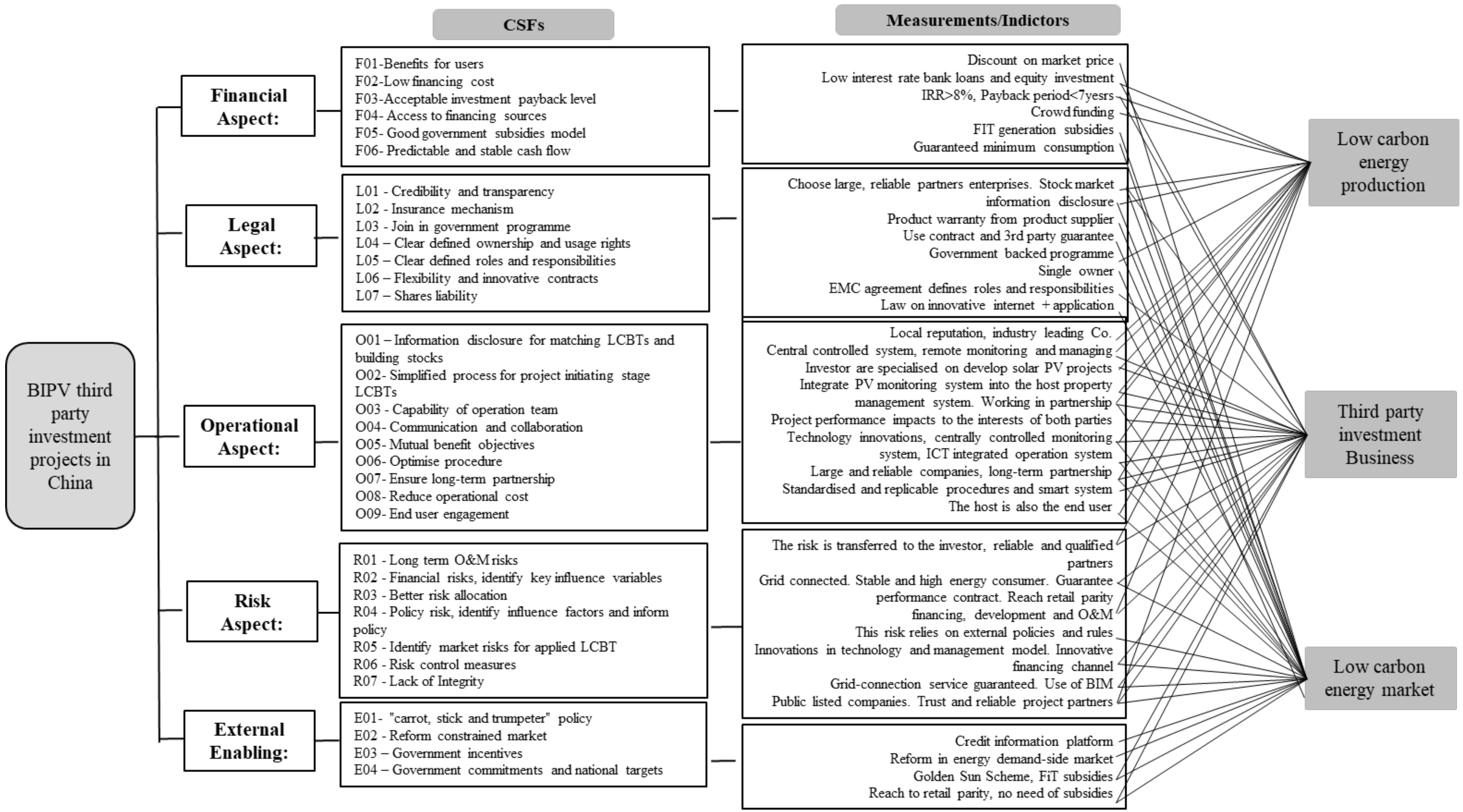
7.5.4 Low carbon energy market

There is a market out there for low carbon energy, including energy consumers, energy retailers, certifiers for green energy, utility authorities for connection to the grid and government permissions and policies. These are the forces and actors characterising the market domain for low carbon energy. They are separated from LCBTs Energy Production before the *Third Party Business* is introduced. The business draws these forces from the market and connects them with LCBTs building projects, facilitating the supply of renewable energy from buildings. For example, in CS3, the third party investor created a partnership alliance that brought together different parties, including a PV products assessor, an IT company, a local utility, local community and investors, to establish a solar electricity purchase platform for individuals to subscribe for certified green electricity generated from CS3 BIPV with a discounted price as well as gaining real-time information about the generation (see Section 7.4.3 in Chapter 7 for more details). The study shows that having introduced the *Third Party Business*, the market forces and actors are motivated to participate in a mutually beneficial and symbiotic LCBTs energy project, consequently, driving the production of low carbon energy.

7.5.5 Evaluation and evidence of workable TpIP through analysing CSFs in BIPV projects in China

The FLORE CSFs are evaluated through case studies on BIPV projects in China. The cross-case triangulation identified corresponding measures and indicators for achieving each CSF, providing evidence of viability and improvement for TpIP application in practice. In addition, CSFs together with their measures are assigned to the groups of *LCBTs Energy Production*, *Low Carbon Energy Market* and *Third Party Business* according to their attributions in the TpIP framework. The results shown in Table 7.22 indicate that *LCBTs Energy Production* and the *Low Carbon Energy Market* are well integrated with the *Third Party Business* - BIPV EMC business.

Table 7.22: Detailed FLORE model to evaluate CSFs of BIPV projects under TpIP Framework in China



7.6 Discussions

7.6.1 Benefit of TpIP framework

The TpIP framework provides an innovative investment model for LCBTs investment, which helps attract finance and increases LCBTs uptake in the building and construction sector. The literature review in this study shows that conventional LCBTs investment a uses self-funding model, costing building developers or owners extra money. In addition, there are split interests and lack of connection between investors and end users (see Section 2.3.5 in Chapter 2). The result of the TpIP framework reveals that TpIP overcomes these barriers by introducing a third party investment business connecting the production and market sides of low carbon building energy. Hence, it encourage actors in both private and public sectors to participate in LCBT diffusion.

7.6.2 Development of TpIP framework

The development of the TpIP framework in this study was an exploring, discovering and evolving process. Findings from reviewing other studies shows that third party investment is simply seen as a financing mechanism for LCBTs adoption (see Section 3.2.2 in Chapter 3). The framework developed from the literature review is presented mainly from the stakeholders' relationship point of view, illustrating the monetary flow between actors and emphasizing the energy saving benefits of adopting LCBTs (see Section 3.2 in Chapter 3). The findings from expert interviews reveals a stakeholder structure for a third party investment business model for LCBT projects. It focuses on project and actor resources for the development of LCBT projects (see Section 6.4 in Chapter 6). The final TpIP framework was developed and refined through observations and investigation of case study BIPV projects in China. The findings from the case studies revealed a bigger picture of TpIP application in practice and discovered three elements and their connections within the TpIP model; namely the *LCBTs Energy Production* forces and *Low Carbon Energy Market* forces are being connected by the agency of the *Third Party Business* (see Section 7.6 in Chapter 7). The refined TpIP framework is abstracted from the case studies of BIPV projects in China and is transferable to other types of low carbon energy building projects, and can be applied to other countries by adjusting settings for different technologies and socio-economic contexts.

7.7 Chapter Summary

Three BIPV case studies were selected for testing and refining the TpIP framework. Each case study project was analysed separately for its stakeholders' structure and CSFs were evaluated for FLORE aspects. Cross-case triangulation was then used to further refine and validate the detailed TpIP framework for BIPV projects in south China. The findings from the case studies revealed that the TpIP framework consists of two forces, LCBTs Energy Production and Low Carbon Energy Market, which are brought together by an agency, the Third Party Business. The core of the TpIP is the Third Party Business, it attracts the forces and actors from both production and market side to work together towards a better performed LCBTs building project. The results of case study analysis confirmed that the TpIP framework business removed financial and risk barriers faced by the host company and encouraged investment in BIPV projects.

Chapter 8 Conclusions and Recommendations

8.1 Introduction

This study developed a Third Party Investment Partnership (TpIP) framework for building integrated low carbon technology projects in China. In developing the framework, a comprehensive literature review, expert forum and three case studies were conducted. In this chapter, the aims and objectives of this study are reviewed, and how they are achieved and developed through presenting the key study findings. This chapter further presents important areas where this study makes an original contribution. Finally, it discusses the limitations of this study, and proposes recommendations and opportunities for future research.

8.2 Review of Research Objectives

Chapter 1 of this thesis set out the aim of this research, which was to develop a TpIP framework that encourages investment in private sector-led building-integrated low carbon technology projects in China. In order to fulfil this aim, the study was guided by achieving the following five research objectives:

1. To identify drivers and barriers for LCBTs investment in private sector building projects

2. To explore third party investment models and draw lessons from successful examples of LCBTs around the world

3. To identify and evaluate critical success factors (CSFs) that are applicable for low carbon building projects in China

4. To develop a conceptual third party investment partnership framework encapsulating CSFs, drivers and barriers representing financial, legal, operational and risk parameters for LCBT projects in China

5. To develop, test and validate a detailed TpIP framework through building integrated photovoltaics projects in south China

Qualitative research methods and techniques including a comprehensive literature review, a two-round expert forum and three case studies (including semi-structured interviews, on-site observation and document review) were adopted in this research. Chapter 5 explained the research methodology and detailed research process. Table 8.1 below summarises the research methods used for each objective.

Table 8.1: Research Method used to achieve objectives (Author's own)

Objectives Number	1	2	3	4	5
Literature review	√	√	√	√	√
Expert forum			√	√	
Case studies				√	√

In the next section, findings from this study are presented and used to demonstrate how each objective has been achieved.

8.3 Summary of Research Findings

The major findings emanating from this study are summarised under the five research objective headings as described in the following sections.

8.3.1 Identify drivers and barriers for LCBTs investment in buildings in both global and Chinese contexts

There were two stages of research conducted to achieve this objective. Firstly, in order to identify drivers and barriers for LCBTs adoption in general, a comprehensive review of literature was carried out to understand global challenges, low carbon building development and low carbon building technologies and LCBTs investment. A list of drivers and barriers for LCBTs adoptions was identified through the literature review process. Secondly, expert interviews were conducted to identify the key drivers and barriers for LCBTs investment in private sector building projects in China.

8.3.1.1 Drivers for LCBTs investment in buildings projects

16 drivers were identified for LCBTs adoption in general (see Appendix A.2) in the first stage. The literature reveals that drivers for LCBTs are different for different scenarios, such as for whom, in which countries and for what type of technologies. Drivers can also change over a period of time. For example, in the early deployment stage of a new LCBT, government incentives are the main driver. Once the technology becomes mature and cost effective, the business driver will take the leading position. Under the pressure of "climate emergency", market demand is an increased influential driver.

In order to identify drivers that can contribute to the development of third party investment model, the research classified LCBTs into 6 types, including low carbon building materials, passive design, building envelope, energy efficient equipment and appliances, renewable energy and carbon offset technologies (see Appendix A.1). The study revealed that three investment models, i.e. self-funding, government-funding and third party funding are used for different types of LCBTs. Self-funding is encouraged for low-cost and short-term return LCBTs. Third party investment models tend to be considered for high upfront costs and profitable LCBTs, which are mostly types of building-integrated energy efficient and renewable energy technologies.

In the second stage, six drivers were identified by the expert forum for a Chinese context (see Table 6.1 in Chapter 6). The study revealed that different stakeholders have different motivations to participate in building-integrated energy efficient and renewable energy technologies in China. Financial benefit is the strongest driver for private sector participants. The environmental driver for Chinese business is not as strong as for Western companies (see Section 6.3.2 in Chapter 6).

8.3.1.2 Barriers to LCBTs investment in buildings projects

35 barriers were identified to LCBTs adoption (see Appendix A.3) in the first stage. The literature also revealed that they can be addressed by one or more approaches. Findings from the literature review show that the barriers, such as high initial costs, split economic interests, lack of finance, risk uncertainty and lack of knowledge, can

be addressed by a third party investment model by outsourcing these issues to a third party who is better equipped to deal with them than the building owner. Other barriers, such as regulatory barriers, can only be removed by policy makers, and 'low priority of energy issues' is mostly related to the mind-set of decision makers. Furthermore, there are barriers, such as high transaction costs, that could be addressed by a combination of an innovative investment model and government policies.

The study further explored barriers to building-integrated low carbon energy projects and investment models in China through a series of expert interviews. The study identified 16 barriers for three groups of participants, namely developers, third party investors and building owners/tenants (see Table 6.2 in Chapter 6). The key barriers for building-integrated low carbon energy projects in China are high capital cost, lack of financing sources, low profitability, complicated ownership structures, high financial risk, lagging laws and regulations, weak market demand and conflict of interests between stakeholders.

8.3.2 Explore third party investment models and lessons learnt from successful examples

The study explored third party investment models from the stakeholders' relationship perspective, and a typical TpIP LCBTs investment stakeholders' relationship model was established by the author at this stage (see Figure 3.2 in Chapter 3). In this model, TpIP was seen as a set of agreements linking Host, Third party investor and Occupier. The third party investor holds the central role establishing relationships with various service providers. The study analysed three successful examples of LCBTs uptake, namely on-bill-financing, third party ownership and energy service contracting, through literature review (see Section 3.2.2 in Chapter 3) and revealed that the common features for the success of these three models mainly lay in the following four aspects:

1. Financial aspect: financial mechanism appropriate for the host country policy and market conditions. Low-interest rate loan for investment makes desirable return;

2. Legal aspect: shifting and balancing costs, risks and responsibilities. Establishing mutually beneficial or symbiotic relationships;

3. Operational aspect: simplified operational process is key for effectiveness and cost reduction. Technology innovation helps reduce operational cost and increase efficiency;

4. Risk aspect: allocating risks and responsibilities to parties who can best manage them; Communicating and dynamically adjusting process.

Drawing lessons from the successful features of existing third party investment models, the study established an analytical framework to investigate Financial, Legal, Operational and Risk aspects (FLOR) for development of a third party investment model in China. The study used this framework to identify and evaluate critical success factors (CSFs) that are applicable for low carbon building projects in China.

8.3.3 Identify and evaluate critical success factors (CSFs) that are applicable for low carbon building projects in China

The two-round expert forum process identified and evaluated critical success factors (CSFs) that are applicable for low carbon building projects in China. In the first round of interviews, the study adopted a thematic analysis method and identified a set of 23 CSFs (see Figure 6.3 in Chapter 6). The findings revealed that the External enabling conditions, such as government policies and market conditions are critical to the success of LCBTs project. Thus, this aspect is added on forming a FLORE model (Financial, Legal, Operational, Risk and External enabling conditions). The study further identified 32 CSFs for the FLORE aspects of TpIP project (see Figure 6.5 in Chapter 6).

Findings in this stage also include identification of finance as a key financial measure to accelerating investment on adoption of LCBTs, addressing capital intensive and long-term payback financial challenges.

8.3.4 Develop a conceptual third party investment partnership framework encapsulating CSFs, drivers and barriers representing financial, legal, operational and risk parameters for LCBT projects in China.

Stakeholder relationship model

Based on the TpIP stakeholders' relationship model established through literature review (see Figure 3.2 in Chapter 3), the study further explored the TpIP framework by conducting a two-round expert forum for a Chinese context. The result of the expert forum in this stage was the establishment of the *TpIP stakeholder structure* (see Figure 6.4 in Chapter 6), which presents a comprehensive stakeholder relationship for a TpIP project in China. The study identified six main actors: Host/Consumer, Third party investor, Source of capital, Sub-contractors, Independent services and Government/authorities, within stakeholders of TpIP. The TpIP stakeholder structure shows that the building-integrated LCBTs project takes the central position and six actors are linked to LCBTs projects through relevant relationships.

The model not only considers actors directly involved in TpIP models, but also includes other actors who are indirectly involved. Some actors can be involved either directly or indirectly in LCBT projects, e.g. financial institutions who are involved for the installation of LCBTs in buildings as they provide the required capital. In a leasing model, financial institutions directly participate in the business as lessor of the equipment.

8.3.5 Develop, test and validate a detailed third party investment partnership framework through building integrated photovoltaics investment in south China

In Chapter 7, deep case study of three BIPV projects and cross-case analysis were conducted to develop, test and validate a final detailed TpIP framework. This was achieved through interviews, document review and site observation methods.

Findings on forces and actors in BIPV project

Findings from cross-case analysis on the stakeholders' structure in each case project (see Figure 7.7, Figure 7.10 & Figure 7.18 in Chapter 7-7.4) revealed that all actors are connected by EMC BIPV, which is the third party business for BIPV projects. All actors can be divided into two sides: rooftop BIPV electricity production and the solar PV energy market (see Table 7.19). Consequently, drivers, barriers and associated CSFs are also divided into the two forces.

Findings on forces and actors in PV energy market:

The review of the Chinese solar PV energy market and policy revealed that China's changing national policy has had a big influence on the PV energy market. The DPV systems have good economic performance and higher investment value in most areas in China. The research has revealed that the changing policy in the PV sector indicates the Government initiative has played a significant role in technological improvement and cost reduction. It encouraged a competitive market and has helped to bring the cost of solar electricity to the point that it can compete with conventional energy without subsidies.

Cross-case study analysis shows a pattern of interaction and evolution between case studies and external enabling conditions over the years. It indicates that China is not a purely "top-down" market. Bottom-up influences also drive industry growth. A trend of the private sector taking a lead was identified.

Findings on forces and actors on BIPV production

Financial benefits and the financing mechanism were still the most influential factors. Low-cost financing is a key success factor for BIPV investment. For the legal aspect, an EMC model works for a BIPV project. The operation CSFs revealed technology innovation, controlled management and optimized operation procedures are critical to the success of BIPV investment. Also, risk allocation to project participants was satisfied. Various measures were evaluated against risk CSFs. Finally, the external enabling conditions prove the CSFs with solid supporting evidence.

Findings in refined TpIP framework

To make a TpIP works, there should be low carbon building technologies energy production forces meet with the low carbon energy market forces, with a third party business acts as an agent to bring the two sides together.

8.4 Original Contribution to Knowledge

8.4.1 Contribution to knowledge

This thesis makes a number of significant and original contributions to knowledge and methodology in the area of low carbon building technologies adoption and investment in building projects.

8.4.1.1 Theoretical contributions

TpIP framework for LCBTs investment

The main contribution of this research is the development of a risk and benefit sharing TpIP framework that encourages investment in LCBTs in building projects. The original contribution to knowledge of this TpIP framework is that, within this TpIP framework, two forces, *LCBTs Energy Production* and the *Low Carbon Energy Market*, are brought together by an agency, the *Third Party Business* (see Section 7.6 in Chapter 7). It presents an abstracted concept derived from analysing rich data collected from comprehensive literature, deep interviews and case studies. Unlike other existing studies focusing on specific aspects, such as financial models, stakeholder relationships or business models, this research first proposed a conceptual framework of the business acting in an agency role to bring production forces and market forces together to form a mutually beneficial or symbiotic partnership for low carbon energy building projects. The framework provides an insight into how forces and actors can be brought together by business to make TpIP work. Currently, no such framework exists and this knowledge is believed to enhance the success of TpIP LCBTs projects.

Drivers and barriers for LCBTs low carbon energy projects in China

In developing the TpIP framework, drivers and barriers were identified for LCBTs low carbon energy projects in China (see Sections 6.3.2 & 6.3.3 in Chapter 6). The drivers and barriers were identified for different key actors within the TpIP framework, which makes communication more relevant and targeted when promoting TpIP to different actor groups.

TpIP Stakeholder structure model for LCBTs building projects in China

The study developed a stakeholders' structure of TpIP projects in China. The TpIP stakeholders' structure comprises six main actors: Host, Third party investor, Source of capital, Sub-contractors, Independent services and Government/authorities. The actors are divided into two sides, *LCBTs Energy Production* and the *Low Carbon Energy Market,* under the TpIP framework. They are joined by the LCBT energy project.

CSFs for TpIP low carbon energy building projects in China

This study identified a set of CSFs under FLORE aspects of TpIP building-integrated low carbon energy projects in China. It has been tested and validated through BIPV case study projects in China. The set of CSFs provides an assessment tool to evaluate the viability of a TpIP application in practice. It can also help to identify measures and improvements by bringing different forces and actors together in achieving each CSF.

8.4.1.2 Methodology contributions

Cross-language research interview data collection and analysis technique

The research explored a method to keep data consistent when doing analysis in cross-language research. The researcher created a template and procedure for interview data transcripts, translation and format for analysing in NVivo, which could be of benefit to other research as reference (Section 6.2.3 in Chapter 6).

Multi-layer triangulations

The study conducted multi-layer triangulation to enhance the validity and transferability of the research result (see Section 5.5 in Chapter 5). The first layer is multi-method triangulation: the study adopted a literature review, an expert forum and case studies for the development of TpIP framework. The second layer is within-case triangulation. It uses interview, site observation and document review to test and develop a detailed TpIP framework within a case study. Finally, the third layer is cross-case triangulation: the study used findings in three case studies, then refined and validated the final TpIP framework.

Internal and external transferability

In addition, this research provides both internal and external transferability. It works for BIPV projects in south China and is transferable to BIPV projects in other regions with similar climates. Moreover, the refined TpIP framework was derived from BIPV case studies and the framework was further cross checked with the expert forum and literature and abstracted to a more generalizable TpIP. Therefore, it would be applicable for other suitable building-integrated low carbon energy technologies, such as ground-source heat-pumps and biomass heating.

Furthermore, this study provides evidence of real social benefits for property developers, owner-occupiers, tenants and project partners. It can inform a wide spectrum of stakeholders and users including policy makers, academic institutions and financial institutes with potential socio-economic benefits in the construction sector. As a result, it will benefit the natural environment by reducing carbon emissions and the risks of climate change, identified at the start of this thesis.

8.4.2 Research limitations

This research project sought to develop a detailed and contextualised framework, rather than a generalisable framework. The expert forum and case studies were purposefully selected for a Chinese context to provide a rich understanding and in-depth knowledge of the research perspective (Herriott & Firestone, 1983; Meredith, 1998). The case study research method may cause concern for its external validity, in other words, how the research results can be generalised or transferred to other contexts or settings (Herriott & Firestone, 1983; Patton, 1990). This research enhances its external transferability by using replication logic in a multiple case study approach (Yin, 2009). Also, by thoroughly describing the research context and the assumptions, it can provide base evidence to other researchers who wish to transfer the results to a different context and judge how efficacious the transfer is (Eisenhardt, 1989).

8.5 Conclusion and Recommendations

8.5.1 Conclusion

The building sector has the highest energy saving and CO_2 emission reduction potential compared to other sectors. Building owners and property developers are reluctant to invest in LCBTs on their buildings due to unclear benefits and a number of barriers. On the other hand, low carbon technologies such as the solar PV market are growing rapidly. Investors and service providers have seen potential investment and business opportunities in low carbon building technologies. There is a need to develop a partnership model to bring stakeholders in low carbon building, low carbon technologies and markets together to create a market-driven force for LCBTs deployment.

A third party investment partnership provides a framework for low carbon building project stakeholders to join together, making procurement meet the market, hence encouraging LCBTs investment for private sector-led low carbon building projects. The TpIP framework is a benefits-sharing and risk-reducing business model. The study suggests that to make the framework work, it should meet a set of success requirements from five aspects: financial, legal, operational, risk and external enabling conditions.

This research developed, tested and validated the TpIP framework through three BIPV case study projects in south China. The results show that all actors within the TpIP framework make contributions to the success of the BIPV case projects, and gain benefits from application of PV power generation system on buildings. Barriers to adopting BIPV in conventional building projects can be overcome within a TpIP framework. Because one party or measure can only partially overcome a limited barriers, the remaining barriers can be solved by actors working together in partnership.

The case study triangulation validates the TpIP framework developed in this study and is workable for BIPV low carbon building projects providing they meet the criteria of CSFs for FLORE. The participants believed that the framework would offer useful knowledge and provide an overall map for improvement to bring stakeholders together in achieving each CSF.

8.6 Recommendations

Based on the findings of this research, the following recommendations are proposed for China:

- Currently there is a lack of financing sources for SMEs engaging with LCBT investments. Short-term bank loans are not suitable for long-term payback investment. More flexible financing sources should be available to SMEs, as they are the potential main group of TPIs for LCBTs projects for individual buildings.

- There is an urgent need to establish a financing channel that provides access to low-cost financing, particular for private companies. Currently, government low interest rate funds are not available for low carbon building projects. The study recommends that the government should allow a state development bank or public fund to finance low carbon building projects, thus lowering the cost of capital for LCBTs investment.

- Currently, this TpIP model is only suitable for industrial and commercial buildings in China. China has a large amount of residential building blocks in cities. If the Government can issue ownership and usage rights for multi-family building rooftops, it will lead to increased market demand for TpIP applications.

- Crowdfunding has potential for BIPV investment, however, its legal status is unclear in China. There is a need to set up crowdfunding and relevant Internet law to regulate and inspect innovation Internet + applications, therefore, avoiding fraud and increasing credibility.

8.7 Future research

Some of the findings in this research provided possible direction for further research in the following areas:

- To develop a TpIP financial model and to identify key variables and risks, which help improve risk and benefit sharing among stakeholders, thus increasing investment attraction.

- Research into end-user engagement for LCBTs investment. To establish a platform that provides opportunities for the end-user to engage with LCBTs investment. It can also increase the social impact of low carbon investment.

- It would be interesting to develop, test and validate a TpIP framework for different types of LCBTs other than BIPV. Use case study triangulation to reform the theoretical framework of TpIP. This study provides a starting point to other LCBT potentials, such as heating and cooling.

- It would also be interesting to develop, text and validate TpIP framework in different countries or regions, comparing the framework development under different social or economic contexts.

REFERENCES

Abdel-Wahab, M., Moore, D., & MacDonald, S. (2011). Exploring the adoption of low carbon technologies by Scottish housing associations. *International Journal of Low-Carbon Technologies, 6*(4), 318-323. doi:10.1093/ijlct/ctr031

Al-Saleh, Y., & Mahroum, S. (2014). A critical review of the interplay between policy instruments and business models: greening the built environment a case in point. *Journal of Cleaner Production*(Journal Article). doi:10.1016/j.jclepro.2014.08.042

Allen, S. R., Hammond, G. P., & McManus, M. C. (2008). Prospects for and barriers to domestic micro-generation: A United Kingdom perspective. *Applied Energy, 85*(6), 528-544. doi:10.1016/j.apenergy.2007.09.006

Andrews, C. J., & Krogmann, U. (2009). Explaining the adoption of energy-efficient technologies in US commercial buildings. *Energy and Buildings, 41*(3), 287-294. doi:10.1016/j.enbuild.2008.09.009

Arrhenius, S. (1896). On the influence of carbonic acid in the air upon the temperature of the ground. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 41*(251), 237-276.

Balaras, C. A. (1996). The role of thermal mass on the cooling load of buildings. An overview of computational methods. *Energy & Buildings, 24*(1), 1-10. doi:10.1016/0378-7788(95)00956-6

Beretka, J., & Mathew, P. J. (1985). NATURAL RADIOACTIVITY OF AUSTRALIAN BUILDING-MATERIALS, INDUSTRIAL-WASTES AND BY-PRODUCTS. *HEALTH PHYSICS, 48*(1), 87-95.

BIS. (2010). *ESTIMATING THE AMOUNT OF CO2 EMISSIONS THAT THE CONSTRUCTION INDUSTRY CAN INFLUENCE*. Retrieved from London:

Brown, M. A. (2001). Market failures and barriers as a basis for clean energy policies. *Energy Policy, 29*(14), 1197-1207. doi:http://dx.doi.org/10.1016/S0301-4215(01)00067-2

Brundtland, G. H. (1987). *Our common future*. Oxford: Oxford University Press.

Caird, S., Roy, R., & Herring, H. (2008). Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency, 1*(2), 149-166. doi:10.1007/s12053-008-9013-y

Chan, H.-Y., Riffat, S. B., & Zhu, J. (2010). Review of passive solar heating and cooling technologies. *Renewable and Sustainable Energy Reviews, 14*(2), 781-789. doi:10.1016/j.rser.2009.10.030

Chen, G. Q., Chen, H., Chen, Z. M., Zhang, B., Shao, L., Guo, S., . . . Jiang, M. M. (2011). Low-carbon building assessment and multi-scale input–output analysis. *Communications in Nonlinear Science and Numerical Simulation, 16*(1), 583-595. doi:10.1016/j.cnsns.2010.02.026

Chowdhury, A. N., Chen, P. H., & Tiong, R. L. (2011). Analysing the structure of public–private partnership projects using network theory. *Construction Management and Economics, 29*(3), 247-260.

Construction, M. H. (2013). *World Green Building Trends SmartMarket Report*. Retrieved from

Couture, T., & Gagnon, Y. (2010). An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. *Energy Policy, 38*(2), 955-965.

DAI, Y.-x. (2009). The Necessity and Governance Model of Developing Low Carbon City in China [J]. *China Population Resources and Environment, 3*, 007.

Dakwale, V. A., & Ralegaonkar, R. V. (2011). Review of carbon emission through buildings: threats, causes and solution. *International Journal of Low-Carbon Technologies, 7*(2), 143-148. doi:10.1093/ijlct/ctr032

DCLG. (2006). *Code for sustainable homes: A step-change in sustainable home building practice*. London: Department for Communities and Local Government.

DECC. (2010). *The Green Deal: A summary of government proposal*. (Ref: 10D/996). Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47978/1010-green-deal-summary-proposals.pdf.

DECC. (2011). *UK Renewable Energy Roadmap*. London: Department of Energy & Climate Change

DECC. (2014). *Research into the Green Deal and ECO Programme Supply Chain*. (14D/266). London: DECC Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/421010/P10_GD_Supply_chain_research.pdf.

Drury, E., Miller, M., Macal, C. M., Graziano, D. J., Heimiller, D., Ozik, J., & Perry Iv, T. D. (2012). The transformation of southern California's residential photovoltaics market through third-party ownership. *Energy Policy, 42*(Journal Article), 681-690. doi:10.1016/j.enpol.2011.12.047

Eichhammer, W., Ragwitz, M., & Schlomann, B. (2013). FINANCING INSTRUMENTS TO PROMOTE ENERGY EFFICIENCY AND RENEWABLES IN TIMES OF TIGHT PUBLIC BUDGETS. *ENERGY & ENVIRONMENT, 24*(1-2), 1-26. doi:10.1260/0958-305x.24.1-2.1

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *The Academy of Management Review, 14*(4), 532-550.

Fan, Y., & Hao, G. (2012, 2012). *Research on development bottlenecks of China's low-carbon buildings based on the method of DEMATEL.* Paper presented at the 2012 International Conference on Information Management, Innovation Management and Industrial Engineering

Gan, G. (1998). A parametric study of Trombe walls for passive cooling of buildings. *Energy & Buildings, 27*(1), 37-43. doi:10.1016/s0378-7788(97)00024-8

Giabaklou, Z., & Ballinger, J. A. (1996). A passive evaporative cooling system by natural ventilation. *Building and Environment, 31*(6), 503-507. doi:10.1016/0360-1323(96)00024-8

Gillich, A., Sunikka-Blank, M., & Ford, A. (2017). Lessons for the UK Green Deal from the US BBNP. *Building Research & Information, 45*(4), 384-395.

Gillingham, K., & Sweeney, J. (2012). Barriers to implementing low-carbon technologies. *Climate Change Economics, 3*(04), 1250019.

Häkkinen, T., & Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information, 39*(3), 239-255.

Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. *Proceedings of the Institution of Civil Engineers, Energy, 161*(2), 87-98. doi:10.1680/ener.2008.161.2.87

Han, H. J., Jeon, Y. I., Lim, S. H., Kim, W. W., & Chen, K. (2010). New developments in illumination, heating and cooling technologies for energy-efficient buildings. *Energy, 35*(6), 2647-2653. doi:10.1016/j.energy.2009.05.020

Hannon, M. J., Foxon, T. J., & Gale, W. F. (2013). The co-evolutionary relationship between Energy Service Companies and the UK energy system: Implications for a low-carbon transition. *Energy Policy, 61*, 1031-1045. doi:https://doi.org/10.1016/j.enpol.2013.06.009

Hastings, S. R., & Wall, M. (2009). *Sustainable solar housing*. London: Earthscan.

Herriott, R. E., & Firestone, W. A. (1983). Multisite qualitative policy research: Optimizing description and generalizability. *Educational researcher*, 14-19.

Heurkens, E. (2012). *Private Sector-led Urban Development Projects: Management, partnerships and effects in the Netherlands and the UK* (Vol. 4): TU Delft.

HOUGH, G. (1997). *Risk sharing partnerships.* Paper presented at the Managing Risks in Projects: Proceedings of the IPMA Symposium on Project Management 1997, Helsinki, Finland, 17-19 September, 1997.

Houser, T. (2009). The economics of energy efficiency in buildings. *Peterson Institute for International Economics Policy Brief No. BB09-17*.

IEA. (2008). *Energy Technology Perspectives 2008*. Retrieved from

IEA. (2018). *2018 Global Status Report: towards a zero‐emission, efficient and resilient buildings and construction sector*. Retrieved from www.globalabc.org

IISD. (2012). *Sustainable Development Timeline*. Retrieved from http://www.iisd.org/

IPCC. (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]*. Retrieved from Geneva, Switzerland:

Isiadinso, C., Goodhew, S., Marsh, J., & Hoxley, M. (2011). Identifying an appropriate approach to judge low carbon buildings. *Structural Survey, 29*(5), 436-446. doi:10.1108/02630801111182457

Johnson, C., Bosher, L., Adekalan, I., Jabeen, H., Kataria, S., Wijitbusaba, A., . . . Arefian, F. (2013). Private sector investment decisions in building and construction: increasing, managing and transferring risks. *Geneva, UNISDR (United Nations International Strategy for Disaster Reduction}*.

Juan, D. (2012). Brighter Days For Solar Power. *China Daily*. Retrieved from http://usa.chinadaily.com.cn/business/2012-10/27/content_15850901.htm [Accessed 27.10.2012]

Kats, G., & Capital, E. (2003). *Green building costs and financial benefits*: Massachusetts Technology Collaborative Boston, MA.

Khan, N., Su, Y., & Riffat, S. B. (2008). A review on wind driven ventilation techniques. *Energy & Buildings, 40*(8), 1586-1604. doi:10.1016/j.enbuild.2008.02.015

Kumar, R. (2011). *Research methodology: a step-by-step guide for beginners*. Los Angeles, [Calif.]: SAGE.

Lam, P. T., Lam, P. T., YU, J. S., & YU, J. S. (2016). Developing and managing photovoltaic facilities based on third-party ownership business models in buildings. *Facilities, 34*(13/14), 855-872.

Li, J. (2008). Towards a low-carbon future in China's building sector—A review of energy and climate models forecast. *Energy Policy, 36*(5), 1736-1747. doi:10.1016/j.enpol.2008.01.029

March, C. (2009). Finance and Control for Construction. In. Hoboken: Taylor and Francis.

Mary, T. H., & Patrick, L. (2004). Choosing the Appropriate Methodology: Understanding Research Philosophy. *The Marketing Review, 4*(4), 397-409. doi:10.1362/1469347042772428

Meadows, D. H. (1972). *The Limits to growth*. London: Earth Island Ltd.

Mebratu, D. (1998). Sustainability and sustainable development: historical and conceptual review. *Environmental impact assessment review, 18*(6), 493-520.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management, 16*(4), 441-454.

Mohanty, A. K., Misra, M., & Drzal, L. T. (2002). Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World. *Journal of Polymers and the Environment, 10*(1), 19-26. doi:10.1023/a:1021013921916

Monahan, J., & Powell, J. C. (2011). An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. *Energy & Buildings, 43*(1), 179-188. doi:10.1016/j.enbuild.2010.09.005

Nair, G., Gustavsson, L., Mahapatra, K., Institutionen för teknik och hållbar, u., Mittuniversitetet, & Fakulteten för naturvetenskap, t. o. m. (2010). Owners perception on the adoption of building envelope energy efficiency measures in Swedish detached houses. *Applied Energy, 87*(7), 2411-2419. doi:10.1016/j.apenergy.2010.02.004

Nelson, A., Rakau, O., & Dörrenberg, P. (2010). Green buildings: a niche becomes mainstream. *Deutsche Bank Research*.

O'Keeffe, J. M., Gilmour, D., & Simpson, E. (2016). A network approach to overcoming barriers to market engagement for SMEs in energy efficiency initiatives such as the Green Deal. *Energy Policy, 97*, 582-590.

Pappu, A., Saxena, M., & Asolekar, S. R. (2007). Solid wastes generation in India and their recycling potential in building materials. *Building and Environment, 42*(6), 2311-2320. doi:10.1016/j.buildenv.2006.04.015

Paris Agreement. (2015). *Agreement adopted on 12 December 2015 at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change*. Paris: United Nations Treaty Collection.

Pätäri, S., & Sinkkonen, K. (2014). Energy Service Companies and Energy Performance Contracting: is there a need to renew the business model? Insights from a Delphi study. *Journal of Cleaner Production, 66*(0), 264-271. doi:http://dx.doi.org/10.1016/j.jclepro.2013.10.017

Patton, M. Q. (1990). *Qualitative evaluation and research methods*: SAGE Publications, inc.

Qiu. (2009). From green building to low carbon eco-city. *Urban Stud, 16*(7), 1-11.

Qiu, B. (2010). Speech at the Sixth International Conference on Intelligent, Green and Energy Efficient Building & New Technologies and Products Expo. Retrieved from http://www.chinagb.net/news/fugle/20100407/61995-1.shtml [Accessed 27.10.2012]

Ramesh, T., Prakash, R., & Shukla, K. K. (2010). Life cycle energy analysis of buildings: An overview. *Energy and Buildings, 42*(10), 1592-1600. doi:10.1016/j.enbuild.2010.05.007

Reddy, V. B. (2004). Sustainable building technologies. *Current Science, 87*(7), 899-907.

REN21. (2009). *Renewables Global Status Report: 2009 Update*. Retrieved from Paris: http://www.unep.fr/shared/docs/publications/RE_GSR_2009_Update.pdf

Richter, M. (2012). Utilities' business models for renewable energy: A review. *Renewable and Sustainable Energy Reviews, 16*(5), 2483-2493. doi:http://dx.doi.org/10.1016/j.rser.2012.01.072

Ritchie, D. (2011). *Catalysing Early Stage Investment - Addressing the Lack of Early-Stage Capital for Low-Carbon Infrastructure in Developing Economies*. Retrieved from France: http://www.scaf-energy.org/news/pdf/Catalyzing%20Early%20Stage%20Investment.pdf

Roberts, S. (2008). Effects of climate change on the built environment. *Energy Policy, 36*(12), 4552-4557. doi:10.1016/j.enpol.2008.09.012

Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. *RENEWABLE & SUSTAINABLE ENERGY REVIEWS, 15*(8), 3617-3631. doi:10.1016/j.rser.2011.07.014

Sartori, I., & Hestnes, A. G. (2007). Energy use in the life cycle of conventional and low-energy buildings: A review article. *Energy and Buildings, 39*(3), 249-257. doi:10.1016/j.enbuild.2006.07.001

Saunders, M., Lewis, P., & Thornhill, A. (2009). Research Onion. *Research methods for business students*, 136-162.

Smith, P. F. (2007). *Sustainability at the cutting edge: emerging technologies for low energy buildings*: Routledge.

SONG, D.-y., & LU, Z.-b. (2009). The Policy Innovation for China's low-carbon Development [J]. *Journal of Huazhong University of Science and Technology (Social Science Edition), 3*, 021.

Speer, B. (2012). Residential Solar Photovoltaics: Comparison of Financing Benefits, Innovations, and Options. *Contract, 303*, 275-3000.

Stern, N., & Stern, N. H. (2007). *The economics of climate change: the Stern review*: cambridge University press.

Stern, N. H. (2007). *The economics of climate change: the Stern review*. Cambridge: Cambridge University Press.

Susan, S. (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.

Sutrisna, M. (2009). *Research methodology in doctoral research: understanding the meaning of conducting qualitative research.* Paper presented at the Proceedings of the Association of Researchers in Construction Management (ARCOM) Doctoral Workshop held in Liverpool John Moores University. Conducted by ARCOM Liverpool, UK: ARCOM.

UNEP. (2009). *Buildings and Climate Change: Summary for Decision-Makers*. Retrieved from Paris: http://www.greeningtheblue.org/sites/default/files/Buildings%20and%20climate%20change_0.pdf

UNEP. (2010). *Green Buildings and the Financial Sector: An overview of Financial Institution Involvement in Green Buildings in North American*. Retrieved from https://www.unepfi.org/fileadmin/documents/greenbuildings.pdf

Paris Agreement, (2015).

ürge-Vorsatz, D., Danny Harvey, L. D., Mirasgedis, S., & Levine, M. D. (2007). Mitigating CO2emissions from energy use in the world's buildings. *Building Research & Information, 35*(4), 379-398. doi:10.1080/09613210701325883

Waas, T., Hugé, J., Verbruggen, A., & Wright, T. (2011). Sustainable Development: A Bird's Eye View. *Sustainability, 3*(12), 1637-1661. doi:10.3390/su3101637

Walker, G. (2008). What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy, 36*(12), 4401-4405. doi:10.1016/j.enpol.2008.09.032

Weimann, K., Giese, L. B., Mellmann, G., & Simon, F. G. (2003). Building materials from waste. *MATERIALS TRANSACTIONS, 44*(7), 1255-1258.

While, A., Jonas, A. E. G., & Gibbs, D. (2010). From sustainable development to carbon control: eco-state restructuring and the politics of urban and regional development. *Transactions of the Institute of British Geographers, 35*(1), 76-76. doi:10.1111/j.1475-5661.2009.00362.x

WMO. (1986). *Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, Villach, Austria, 9–15 October 1985*. Retrieved from Villach:

Xinhua. (2009). China announces targets on carbon emission cuts. Retrieved from http://news.xinhuanet.com/english/2009-11/26/content_12544181.htm [Accessed 27.10.2012].

Yang, M. (2016). Energy service company and financial market development: experiences of the Global Environment Facility. *Mitigation and Adaptation Strategies for Global Change, 21*(5), 663-676.

Yik, F. W.-H., & Lee, W.-L. (2004). Partnership in building energy performance contracting. *Building Research & Information, 32*(3), 235-243.

Yin, R. K. (2009). *Case study research: design and methods* (4th ed. ed.). Thousand Oaks, Calif: Sage Publications.

Young, E. (2011). *UK solar PV industry outlook: The UK 50kW to 5MW solar PV market*. Retrieved from London:

Zhang, S. (2016). Innovative business models and financing mechanisms for distributed solar PV (DSPV) deployment in China. *Energy Policy, 95*, 458-467. doi:http://dx.doi.org/10.1016/j.enpol.2016.01.022

Zhao, K., Liu, X.-H., Zhang, T., & Jiang, Y. (2011). Performance of temperature and humidity independent control air-conditioning system in an office building. *Energy and Buildings, 43*(8), 1895-1903. doi:10.1016/j.enbuild.2011.03.041

Zhao, X., Zeng, Y., & Zhao, D. (2015). Distributed solar photovoltaics in China: Policies and economic performance. *Energy, 88*, 572-583.

Zhou, L., Ramin, K., & Kurul, E. (2013). Sustainability performance measurement framework for PFI projects in the UK. (Journal Article).

APPENDICES

Appendix A – Table of LCBTs, Drivers and Barriers

A.1 Table of LCBTs From Literature Review

Category	Technologies	Functions / application	Level of adoption	Reference Sources
Low carbon building materials minimising the embodied energy of buildings.	Sustainable sourced natural and bio-based products derived from natural materials, such as soil, thatch/leaves, bamboo, hemp, mud, stone etc.	The new generation of natural/bio materials has increased performance, strength, durability and commercial competitiveness through fibre treatments, bio-resin formulations and modern manufacturing techniques. The products are generally used for interior finishes and non- supporting structural components, such as external wall panel, external cladding kit, internal partition wall and suspended ceiling kit etc. Though some natural materials such as bamboo have been used as supporting structural elements.	The use and acceptance of natural/bio building materials are still limited in construction industry due to their performance limitations and high cost comparing to conventional construction Materials.	(Hammond & Jones, 2008; Mohanty, Misra, & Drzal, 2002) (Reddy, 2004)
	Recycled materials from mining wastes, building wastes, industrial wastes and by-products, such as fly ash block and rubber aggregates.	Materials using recycled content not only require less virgin resources, they also use less energy and chemicals to process. Recycled materials as a substitute to conventional materials like bricks, blocks, tiles, aggregates, ceramics, cement, lime, soil, timber and paint. Many commonly used construction components have already contain a significant proportion of recycled contents, such as concrete block, wall insulation, concrete roof tile, ceiling tiles, intermediate floors, floor coverings.	Recycled materials have widespread used by the construction industrial. Around 30% of the materials used by the European construction industry come from recycled sources. This could rise to 90%.	(Beretka & Mathew, 1985; Pappu, Saxena, & Asolekar, 2007; Reddy, 2004; Weimann, Giese, Mellmann, & Simon, 2003)(WMW,2011)
	Prefabricated and modular building components	Benefits of prefabrication applications compared to traditional construction solutions include: reduction of water, materials and energy used in construction; reduction of construction waste; reduction of	Prefabrication is used to some degree in all aspects of construction. However, the perception of poor quality in parts	(BRE, 2001) (Monahan & Powell, 2011; Roberts, 2008)

Category	Technologies	Functions / application	Level of adoption	Reference Sources
		construction period; cost efficiency; less noise and dust; reusable components; less embodied carbon locked within the fabric of the buildings	of the industry limits the extent of its application. Modern methods of construction (MMC) a new term of high-quality prefabrication will overcome the barriers.	
Passive design (Utilising solar, wind and water)	Passive solar heating and cooling technologies, such as trombe wall, thermosyphoning collectors system, solar chimney	Passive solar technologies provide space heating in winter and cooling in summer through buoyancy or evaporative effects without using active mechanical devices. Passive solar are building integrated whereby facades or roofs are part of the heating or cooling system components. This reduces initial cost, which generally add 0–15% to design and construction costs, and have long life energy saving.	Market adoption is effected by architectural aesthetic, cost effectiveness and system efficiency.	(Chan, Riffat, & Zhu, 2010; Gan, 1998)
	Daylighting devices, such as light tube and reflecting board	Various daylighting devices collect and transmit sunlight for building illumination, reducing the use of electric lighting during daytime. The technologies can avoid the glare and ill effects of direct sunlight, give the right amount of illumination and well distribute light.	Solar illumination systems have gained increased popularity in recent years.	(Han, Jeon, Lim, Kim, & Chen, 2010)
	Sun shading devices	Sun shading avoids direct sunlight to reduce cooling loads and solar gain. Shading devices include overhangs, louvers, and vertical fins, can be fixed-position or adjustable, external or internal.	Widely adopted	
	Energy-free natural ventilation techniques	Energy-free alternative ventilators such as wind cowl and solar chimney to air conditioning using wind power, stack effect or thermal movement to both	Adopted under suitable climate and sites, not suitable for sites with high	(Hastings & Wall, 2009; Khan, Su, & Riffat, 2008)

Category	Technologies	Functions / application	Level of adoption	Reference Sources
		passively cool and ventilate a building. It requires building integrated design.	levels of acoustic noise or poor air quality	
	Breathable window	The window integrated ventilator saves the need to open windows and ensures fresh air supply through air tight window.	Increased uses	
	Passive Evaporative cooling system	Evaporative cooling is used extensively for cooling in climates with medium to low humidity. Application can be integrated into building façade and roof through water falling or roof pond.	Not widely applicable	(Giabaklou & Ballinger, 1996)
Passive Design (Building envelope)	Thermal mass	Walls with high thermal mass absorb and retain heat, and release later, slowing heat gain and lose, hence, reduce cooling and heating load. Thermal mass works well in locations that have a relatively large temperature range from day to night. Phase change materials give increased thermal mass in a narrow temperature range.	Adoption limited by climate conditions Key indicator for building performance in green building rating system.	(Balaras, 1996; Sadineni, Madala, & Boehm, 2011)
	Insulation walls and roofs Hollow core slab	Thermal insulation is a material that blocks or slows the flow of heat through the building envelope, reduce heating and cooling load.	Easy and cost effective to adopt. Key indicator for building performance in green building rating system.	(Sadineni et al., 2011) (Andrews & Krogmann, 2009)
	High performance glazing	Commonly used high performance glazing includes Low-Emittance glazing, double/triple pane, aerogel glazing, vacuum glazing and insulated frames.	Improved building regulations, not willing to pay beyond current standards	(Balaras, 1996; Nair et al., 2010; Sadineni et al., 2011)

Category	Technologies	Functions / application	Level of adoption	Reference Sources
			Key indicator for building performance in green building rating system.	
Energy Efficient Equipment and Appliances	high-efficiency HVAC Boilers, Heat Recovery		Widely adopted	
	Intelligent control system Lighting controls sensors		Widely adopted for office buildings	
	Energy saving lift		Widely adopted for office buildings	
	Energy efficient lighting LED (Light-emitting diode)		Widely adopted	(Smith, 2007)
	The temperature and humidity independent control (THIC) system	THIC controls indoor temperature and moisture separately Humidity control systems add or remove water vapour from indoor air to stay within proper humidity ranges. Case study shows that The COP of the entire THIC system can reach 4.0,		(K. Zhao, Liu, Zhang, & Jiang, 2011)
	Radiant heating and radiant cooling systems. Chilled beam and ceiling	Modern radiant heating systems are generally heated floors. Radiant cooling systems are generally chilled ceiling beams or panels		
	Other low energy cooling systems	Ground coupling using air Groundwater/aquifer cooling and warming Evaporative cooling Phase change cooling		

Category	Technologies	Functions / application	Level of adoption	Reference Sources
		Solar-assisted desiccant dehumidification with air conditioning Refrigeration Ammonia-absorption cooling Thermionic cooling		
Renewable Energy	Solar thermal	relatively reliable and predictable Proven/established technology Visually unobtrusive		(Allen, Hammond, & McManus, 2008; Smith, 2007)
	Solar PV	relatively reliable and predictable, Proven	High capital costs Not currently cost effective, Policy driven, huge potential, integrated with architectural design	(Allen et al., 2008; Smith, 2007)
	Micro-wind		relatively inexpensive, Very site specific resource, Not currently cost effective	(Allen et al., 2008)
	Ground-source heat-pumps	High capital costs	Very reliable, cost effective	(Allen et al., 2008; Smith, 2007)
	Micro-CHP		Currently mostly fossil fuel powered, cost effectiveness	(Allen et al., 2008; Smith, 2007)
	Biomass heating		site specific, limited by the availability of suitable	(Allen et al., 2008)

Category	Technologies	Functions / application	Level of adoption	Reference Sources
			locations. Can be cost effective	
	Micro-hydro		site specific, limited by the availability of suitable locations, Can be cost effective	(Allen et al., 2008; Smith, 2007)
	Fuel cells			(Smith, 2007)
	Biofuel			
	Anaerobic digestion from waste			(Smith, 2007)
	Tidal energy		project-specific	(Smith, 2007)
	Geothermal energy			(Smith, 2007)
	Air source heat pump			
Carbon offset / sink	Roof garden			
	Vertical green walls			

A.2 Drivers from literature review

Code	Drivers	Source reference
LRD01	Government incentives	(Caird, Roy, & Herring, 2008; UNEP, 2010) (UNEP, 2010) (Construction, 2013) (DECC, 2011) (N. H. Stern, 2007) (Nelson et al., 2010) (McGraw Hill Construction, 2023) (Al-Saleh & Mahroum, 2014) (Porter and Kramer, 2011) (Häkkinen & Belloni, 2011)
LRD02	Market Demands	
LRD03	Business Investment opportunity	
LRD04	Price drop of renewable energy technologies	
LRD05	Increasing awareness	
LRD06	energy cost reduction	
LRD07	Increasing the property value	
LRD08	Operating cost benefits	
LRD09	‘Sticks’ policy (Obligations, mandatory, Codes, Standards, Carbon Taxes)	
LRD10	‘Carrots’ policy incentives Feed-in Tariffs, Subsidies, Grants, Tax Credits, Tendering	
LRD11	‘Sermons’ policy, social value-based market Information, Labelling, Awareness, Campaigns	
LRD12	Corporate social responsibility	
LRD13	Increase comfort	
LRD14	Concern for environment	
LRD15	Building regulations	
LRD16	Planning policy	

A.3 Barriers from literature review

<table>
<tr><th>Code</th><th>Barriers</th><th>Reference</th></tr>
<tr><td>LRB01</td><td>Extra cost</td><td rowspan="35">(Kats & Capital, 2003; UNEP, 2010)
(Zhou, 2013)
(Carbon Trust, 2005)
(Abdel-Wahab, 2011)
(Al-Saleh & Mahroum, 2014) (Cornes and Sandler, 1996; Foxon and Pearson, 2008; Jaffe and Stavins, 1994; Marques et al., 2013; Weber and Rohracher, 2012)
(UNEP, 2010)
(Brown, 2001)
(Hausman, 1979; Ruderman et al., 1987; Ross, 1990; Levine et al., 1995)
(Huijben and Verbong, 2013; IEA-RETD, 2013; Lovins, 1992)
(Kostka and Shin, 2013; Lo, 2014).
(Gillingham & Sweeney, 2012)
(Häkkinen & Belloni, 2011)</td></tr>
<tr><td>LRB02</td><td>No direct benefits</td></tr>
<tr><td>LRB03</td><td>Hidden costs / benefits</td></tr>
<tr><td>LRB04</td><td>knowledge gap in performance of LCBTs</td></tr>
<tr><td>LRB05</td><td>Market failures
imperfect competition; distortionary fiscal, economic and regulatory policies; and asymmetric information</td></tr>
<tr><td>LRB06</td><td>Misplaced incentives principal-agent problem</td></tr>
<tr><td>LRB07</td><td>Capital market barriers-“interest rate gap”</td></tr>
<tr><td>LRB08</td><td>Low priority</td></tr>
<tr><td>LRB09</td><td>Information gaps</td></tr>
<tr><td>LRB10</td><td>Short time horizons</td></tr>
<tr><td>LRB11</td><td>Non-separability of energy equipment</td></tr>
<tr><td>LRB12</td><td>Uncertainty of future energy prices</td></tr>
<tr><td>LRB13</td><td>Incomplete markets</td></tr>
<tr><td>LRB14</td><td>Complexity and hassle disincentives</td></tr>
<tr><td>LRB15</td><td>Split incentives’ - ‘landlord/tenant</td></tr>
<tr><td>LRB16</td><td>investment risks - inconsistent policy</td></tr>
<tr><td>LRB17</td><td>lack of trustworthy relationships</td></tr>
<tr><td>LRB18</td><td>Targeting the low-hanging fruit</td></tr>
<tr><td>LRB19</td><td>CSR focus on boosting reputation with a limited connection to business</td></tr>
<tr><td>LRB20</td><td>Too expensive</td></tr>
<tr><td>LRB21</td><td>Too much trouble to install</td></tr>
<tr><td>LRB22</td><td>Reputation for unreliability</td></tr>
<tr><td>LRB23</td><td>Unpleasant or unsuitable quality</td></tr>
<tr><td>LRB24</td><td>Insufficient electricity produced</td></tr>
<tr><td>LRB25</td><td>Uncertain performance and reliability</td></tr>
<tr><td>LRB26</td><td>Difficulty find good installer</td></tr>
<tr><td>LRB27</td><td>Gaining planning permission</td></tr>
<tr><td>LRB28</td><td>high social and private costs</td></tr>
<tr><td>LRB29</td><td>split-incentive</td></tr>
<tr><td>LRB30</td><td>Possible risks and unforeseen costs - process changes</td></tr>
<tr><td>LRB31</td><td>Lack of client demand</td></tr>
<tr><td>LRB32</td><td>Not increase the value of the property</td></tr>
<tr><td>LRB33</td><td>Lack of client awareness</td></tr>
<tr><td>LRB34</td><td>Lack of proven alternative technologies</td></tr>
<tr><td>LRB35</td><td>Lack of business case understanding</td></tr>
</table>

Appendix B - Expert Panel Profile for Expert Forum

Table B. 1: Expert Profile Sheet for Expert Forum

Cat.	Personal Details				LCBT related skills				
	Expert Code	Position	Qualification	Years in their field	Design	Finance	Build	Operation	Policies
D	D01	Vice President	MSc, Professor	20 Years		√	√	√	√
D	D02	Vice President	MSc	10 Years	√	√	√	√	
D	D03	Director of Green Building	PhD	10 Years	√	√	√	√	
D	D04	Green R & D Director	PhD	10 Years	√	√	√	√	
I	I01	Sector Director	PhD	10 Years	√	√	√	√	
I	I02	CEO	MSc, MBA	20 years	√	√	√	√	√
C	C01	Green Building Director	PhD	20 Years	√		√	√	√
C	C02	Policy advisor	MSc	10 years		√			√
C	C03	Researcher & Deputy Director	MSc	10 years	√		√	√	√
G	G01	Assistant President	PhD	10 years		√			√

Appendix C – Interview Guidance for the Frist Round Expert Interview

C.1 Interview guidance for conducting the first round of expert interview

Purpose	Interview topics and questions
Sections 1: Expert background and experience	
Get to know participants and his/her organisation background, so that the questions can be more relevant	1.1 Can you talk about your work experience and how it relates to LCBTs?
	1.2 Can you give an introduction about your company/organisation, and how its business relates to LCBTs?
Sections 2: China current situation of LCBTs adoption	
To add the additional local drivers onto the existing list	2.1 What do you think the main drivers to adopt / invest on LCBTs in building projects in China?
	2.2 What are the drivers for your company / organisation to enter LCBTs projects?
To add the additional local barriers onto the existing list	2.3 What do you think the main barriers to adopt / invest LCBTs projects in China?
	2.4 What are the barriers for your company/ organisation of adopting / investing LCBTs?
To gain information on successful /unsuccessful LCBTs models used in China	2.5 How do you / your company finance the LCBTs?
	2.6 What are the current models used on LCBT projects invested by other parties.
	2.7 How do these models perform?
Sections 3: TpIP predictions for China	
Whether TpIP approach is attractive to project stakeholders or not	3.1 Are you or your company interested in using third party investment partnership approach in your projects/premises?
Predictions on the framework structure	3.2 What is your suggestion for the TpIP framework structure if you decided to adopt it?
Adding additional SFs if there are	3.3 What are the key factors for TpIP to be successful?
Predictions on potential risks	3.4 Can you think of any risk for this model?
Free to add any other issue that has not mentioned	3.5 Do you have any other advice on TpIP framework?

Section 4: Close	
Reminder of the next contact timeline, give time to prepare	4.1 Explain the next step and arrange the next contact time. Thank and close the interview.

C.2 Interview guidance in Chinese for conducting the first round of expert interview

问题清单

开场问候。

1. 问：您目前工作的重点是做低碳建筑哪方面呢？
2. 问：您认为在中国投资低碳建筑的动力是什么？
3. 问：在建筑上使用低碳技术中有什么障碍吗？
4. 问：你们给客户咨询和设计绿色建筑时一般都推荐采用哪类的绿色低碳技术？
5. 问：会考虑投资回报吗？（投资建议）
6. 问：客户是否都能接受，并愿意投资呢？
7. 问：哪些技术采用会难一些？
8. 问：一般都是谁来投资低碳建筑技术？
9. 问：如果成熟的话，是否会建议第三方投资模式给客户？不需要他们增加成本。第三方投资合作伙伴模式现在主要包括开发商或业主、技术投资建设运维方、和技术使用方，如用户或建筑管理公司，这三个合作方。
10. 问：您认为他们对第三方投资模式会感兴趣吗？
11. 问：您建议这个第三方合作伙伴的构架是什么样的？（几个合作方？）
12. 问：适合用在什么类型的建筑？
13. 问：适合用在什么类型的技术？
14. 问：您能想到第三方投资模式可能的风险在哪里吗？
15. 问：您认为还有哪些其他方应该参与吗？两方还是三方，或多方签署有法律效用的协议/合同
16. 问：要想在市场上推广，它需要的成功要素有哪些呢？
17. 问：政府的推动和补贴政策是否很有必要？
18. 问：您能预测一下第三方投资的低碳技术运营的方式吗？比如说能源服务，目前国内是比较垄断的，第三方用什么样的模式才能提供这样的服务？
19. 问：您还有其他方面的建议和想法要补充吗？

结束：我们今天的访谈就到这里。下一步我会将访谈资料做汇总和分析，然后起草一个合作伙伴概念性框架，发给您征询您的意见。

谢谢您的时间。

Appendix D – Expert Forum Research Participant Consent Form and Information Sheet Chinese Translation

RESEARCH PARTICIPANT CONSENT FORM 专家访谈同意书

Participant Name 专家姓名:

Organisation 单位:

Project title: Developing A Third Party Investment Partnership Framework For Private Sector Led Low Carbon Building Projects

项目名称：开发由私营主导的低碳建筑项目的第三方投资合作伙伴框架

Researcher's names 研究者姓名: Xiaohong Chen

Supervisors' names 博士导师: Prof. Srinath Perera and Dr. Lei Zhou

University 学校: Northumbria University Newcastle

Standard statement of participant consent 专家访谈同意声明

I have read and understand the purpose of the study and other details provided in the information sheet, and agree to participate. 我已了解研究项目的内容和访谈程序，并同意参与研究访谈。	☐
I have discussed any requirement for anonymity or confidentiality with the researcher.我与研究者已讨论个人身份信息保密要求。	☐
I agree to be audio taped during the interview. 我同意访谈过程中录音。	☐
The use of the data in research, publications, sharing and archiving has been explained to me. 数据在研究、出版物、分享和存档中的使用已向我解释。	☐

Signed 签字..	**Date** 日期......................................
Standard statement by researcher 研究者声明 I have provided information about the research to the research participant and believe that he/she understands what is involved. 我已向访谈专家提供研究信息并相信他／她对所参与的研究过程已理解。 **Researcher's signature** 签名..................................... **Date** 日期.................................	

PARTICIPANT INFORMATION SHEET 有关参与专家访谈信息

目的：

本次专家访谈是为诺森比亚大学的博士研究项目《开发低碳建筑项目第三方投资合作伙伴框架》所做的咨询，目的是针对中国私营主导的低碳建筑项目开发一个鼓励采纳低碳技术的合作模式。该模式可帮助业主／地产开发商解决低碳建筑技术前期投入和运营风险的障碍，由第三方提供建筑低碳设备的投资和维护运营服务，为用户提供经济的运行费用。

参与咨询程序：

本次咨询采用德尔菲法，通过多轮采访和函询专家意见，由研究人员进行汇总分析，最终得出一致认可的结果。专家意见和反馈采用匿名形式，研究人员与专家的互动是一对一进行的。每位专家至少参与以下三次互动：

- 第一次：不超过一个小时的访谈，可采用面谈或电话方式；
- 第二次：研究人员根据对访谈数据的汇总分析，建立初步合作伙伴框架并发给参与专家，通过邮件或对话方式向专家征求意见；
- 第三次：研究人员根据专家反馈修改框架，再将修改结果返回专家，咨询不同意见的原因并获得修正，直到取得一致性的意见，并最终确定框架。

数据和参与风险：

专家提供的数据是跟据个人的知识和经验对未来框架做出的预测和想法，没有参与风险。

权利：

根据 1998 年数据保护法，数据提供者拥有以下权利：

- 可以随时退出和撤销许可
- 可以要求在任何时间访问信息
- 知道联系人和联系方式

保密和匿名：

专家和案例项目匿名，数据不会被泄露。

数据储存：

数据有密码保护，并存储在加密的设备/机器。

发表和结果：

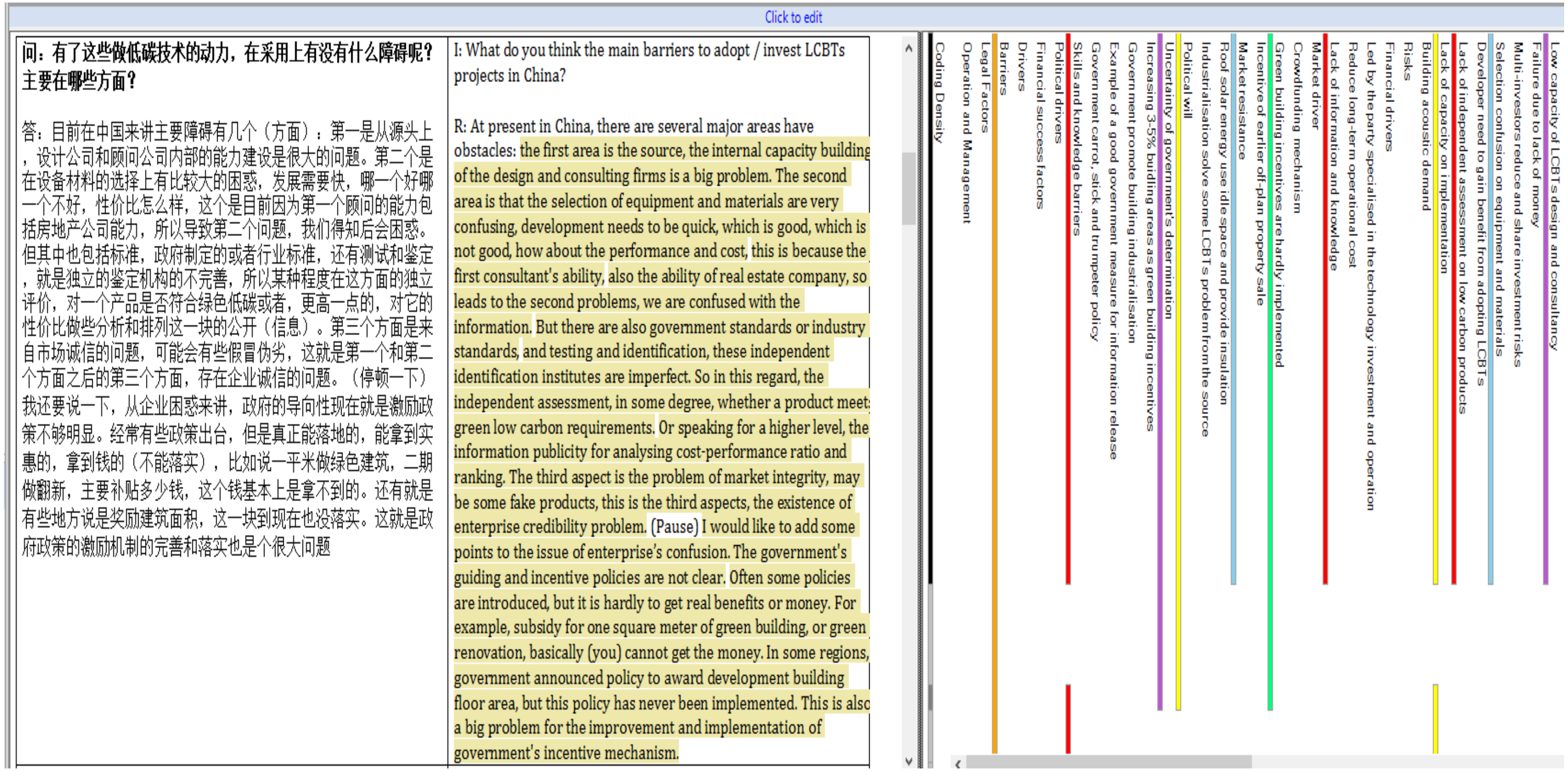
获得的数据将仅用于本项研究。如未获得参与人同意，处理后的数据如要发表将不会透露参与人和案例项目名称。

参与方的好处：

研究者将通过严谨的科学方法开发出来一个全面的、适用中国的、用于低碳建筑项目的合作伙伴框架，参与方是该框架的利益相关方和潜在使用方，研究成果会与参与方分享。此外，该研究的相关出版物会提供给合作方。

Appendix E - Sample of Expert Interviews Transcript, Translation and Data Analysis in Nvivo

Table E.1: Example of expert interviews transcripts, translations and data analysis in NVivo (Author's own)



Click to edit

问：有了这些做低碳技术的动力，在采用上有没有什么障碍呢？主要在哪些方面？ 答：目前在中国来讲主要障碍有几个（方面）：第一是从源头上，设计公司和顾问公司内部的能力建设是很大的问题。第二个是在设备材料的选择上有比较大的困惑，发展需要快，哪一个好哪一个不好，性价比怎么样，这个是目前因为第一个顾问的能力包括房地产公司能力，所以导致第二个问题，我们得知后会困惑。但其中也包括标准，政府制定的或者行业标准，还有测试和鉴定，就是独立的鉴定机构的不完善，所以某种程度在这方面的独立评价，对一个产品是否符合绿色低碳或者，更高一点的，对它的性价比做些分析和排列这一块的公开（信息）。第三个方面是来自市场诚信的问题，可能会有些假冒伪劣，这就是第一个和第二个方面之后的第三个方面，存在企业诚信的问题。（停顿一下）我还要说一下，从企业困惑来讲，政府的导向性现在就是激励政策不够明显。经常有些政策出台，但是真正能落地的，能拿到实惠的，拿到钱的（不能落实），比如说一平米做绿色建筑，二期做翻新，主要补贴多少钱，这个钱基本上是拿不到的。还有就是有些地方说是奖励建筑面积，这一块到现在也没落实。这就是政府政策的激励机制的完善和落实也是个很大问题	I: What do you think the main barriers to adopt / invest LCBTs projects in China? R: At present in China, there are several major areas have obstacles: the first area is the source, the internal capacity building of the design and consulting firms is a big problem. The second area is that the selection of equipment and materials are very confusing, development needs to be quick, which is good, which is not good, how about the performance and cost, this is because the first consultant's ability, also the ability of real estate company, so leads to the second problems, we are confused with the information. But there are also government standards or industry standards, and testing and identification, these independent identification institutes are imperfect. So in this regard, the independent assessment, in some degree, whether a product meets green low carbon requirements. Or speaking for a higher level, the information publicity for analysing cost-performance ratio and ranking. The third aspect is the problem of market integrity, may be some fake products, this is the third aspects, the existence of enterprise credibility problem. (Pause) I would like to add some points to the issue of enterprise's confusion. The government's guiding and incentive policies are not clear. Often some policies are introduced, but it is hardly to get real benefits or money. For example, subsidy for one square meter of green building, or green renovation, basically (you) cannot get the money. In some regions, government announced policy to award development building floor area, but this policy has never been implemented. This is also a big problem for the improvement and implementation of government's incentive mechanism.

Appendix F – CSFs Coding under FLORE Aspect Abstracted From NVivo

The results abstracted from NVivo explained the coding process of expert panel interviews.

Table F.1: CSFs from financial aspect result shown in NVivo

Factors		Coding reference
FF01-Financial benefits for users		E3-22 Cheaper rate
This factor is one of the primary drivers and conditions for developers and owners to entering partnership agreement with 3rd party investors. The project much save money or generate additional income to the adopters or users.		E5-22 Developer benefits (lease fees or cheaper electricity)
		E8-26 cheaper energy cost and operational cost
		E8-26 cheaper energy cost and operational cost
FF02-Low project financing cost for investors		E3-28 Low cost capital
This is one of the key factors affecting the success of the investment. Currently it is not widely available in this industry.		E6-56 Cheap and easy-find financing sources
		E6-75 High borrow rate (barrier)
		E10-19 Require large amount of capital
		E10-26 Low cost financing
		E10-31 Financing cost
FF03-Investment payback	Payback period	E10-24 meet expected investment return level
Chinese investors expects short payback period, normally less then five years. In some cases, upto ten years.		E3-23 System depreciation to investor
		E5-18 Short payback period (developer)<5 years
		E5-19 Long payback period (<10 years) is possible
		E5-20 TpIP payback period <10 years
		E6-68 project profits too small (barrier)
		E6-74 High expected return for investors
		E8-28 Profitability of investment
	Payback methods	E10-17 Return routes, i.e. pay rate or management fees
	Stable cash flow	E10-23 Cash flow
FF04- Access to financing sources	State policy banks	E3-29 low rate from China Development Bank
Allow private companies having access to low cost funds. A new special mechanism to promote this.		E3-33 Use government policy banks
		E6-77 Government incentives change to discounted rate green loan
		E6-79 Government seed funds
		E6-78 Green funds source (ratepayer)
	3rd party financing	E3-30 3rd party financing
		E3-32 Good financial product
		E3-34 Government special mechanism allow long-term low rate funds participating
		E5-31 Crowdfunding - public green investment opportunity
		E6-76 Insurance funds participation

Table F.2: CSFs from legal aspect result shown in NVivo

LF01 - Company credential system	E3-19 Authenticated company
	E3-31 Reliable operating company
	E3-35 Create credit system for company
	E3-42 3rd party assessment
	E3-43 Information platform available
	E6-33 No liability for quality check in China
LF02 - Insurance mechanism	E3-25 Insured safety
Prevent risks	E3-39 Two parties agreement needs guarantee
	E3-44 Underwrite
	E6-34 Transparency in insurance
	E6-35 Security mechanism
	E6-36 Guarantee stable income
LF03 - Government support policy	E3-36 Government do good supervision
	E3-37 Government give away benefit to private sector
	E3-38 Public engagement for public project
	E3-40 Government supervision protect users right
	E5-23 LCBT product policy (legal)
	E5-24 Production surplus policy
	E5-25 Product pricing
	E6-32 Corruption in management (authority)
	E6-85 Policy can break the law
LF04 - Clear ownership	E6-42 Not fully privatization for China residential buildings
	E10-18 Ownership belong to investor
LF05 - Parties' roles and responsibilities	E5-32 Binding contract with purchase or lease contract
	E5-35 Long-term partnership
	E5-36 Leading party - decision making easier
	E6-60 Equity in partnership
	E6-61 Benefits balance point
	E3-26 Smooth with other stakeholder (no opposition from neighbours)

Table F.4: CSFs from operational aspects result in NVivo

OF01- Suitable building types	E3-24 Individual house (villa)
	E6-43 Selecting project building type -Difficult for individual home in China
	E6-44 Unclear roof ownership for residential building China
	E6-45 Start from public usage type project
	E6-46 Suitable building type for project - public, manufactory, productive types
	E6-84 independent system for remote region
	E10-11 Building type
	E10-14 Developer also take property management
OF02 - Select suitable LCBTs	E6-37 Power station is good investment
	E6-38 increased conversion rate (PV)
	E6-39 Capital cost decreasing (PV)
	E6-40 Technologies reduce cost(PV)
	E6-41 Cost parity with fossil fuels(PV)
	E6-72 Movable system
	E10-12 Centralised building facilities
	E10-13 Way of investment payback
	E10-15 Select Energy consumption category
	E10-16 Can be separated out
	E10-27 Large capacity for PV (>MW)
	E3-27 Cheaper electricity
OF03 - Capability of operation team	E5-37 Leading party specialised in the technology investment and operation
	E6-51 Whole life cycle process cost high - initiative, financing, marketing, sell etc.
	E6-86 Improve operational process efficiency with BIM
	E10-20 technology capacity
	E10-21 Strong capacity of operational team
	E10-22 operational capacity
	E10-28 Cost effective project process
	E10-32 Operational team
	E10-33 Shortage of professional for FM
	E3-21 less trouble
OF04 - Reduce conflicts to the building	E5-21 Not disturb building usage
	E5-26 One party - owner
	E5-40 Industrialisation
OF05 - Select suitable parties	E5-27 One party - property management
	E5-28 Three party agreement
	E5-29 More investors participating - reduce & share risks
	E5-30 Wider promotion - awareness raising
	E6-48 EPC led in China
	E6-49 Multi roles for EPC in China inc project development, financing
	E6-50 Initiative by EPC
	E10-14 Developer also take property management
	E6-80 Support policy

RF01 - Long term operation and maintenance risks	E5-34 Long-term maintenance risk
	E6-63 Black sheep (short life company) makes the industry bad reputation - barrier
RF02 - Financial riskes	E5-33 fail due to investor no money
	E6-73 Financing cost too high
RF03 - Better risk allocation	E3-20 Free risk for user
RF04 - Policy risk	E6-81 Monopoly- market barrier
	E6-82 Compete with state grid
	E6-83 Conflict of interest with state grid
RF05 - Market risk	E3-41 No monopoly
	E6-47 Failed in residential building
	E6-52 Many constraint makes uncertainty
	E6-54 State-owned companies active market
	E6-55 Private company do small part
	E6-64 Market irregularity - barrier
	E8-31 monopoly
RF06 - Risk control	E3-45 Controllable risk
	E6-29 Unsecure guarantee by commitment in China
	E6-30 Guarantee by insurance company
	E6-31 Insurance engagement
RF07 - Lack of Integrity risk	E6-59 3rd party weak position in price negotiation - barrier
	E6-62 Untrusted long difficult negotiation, high extra risk for 3rd party - barrier
	E6-65 Design not built (unknown reason)- communication?
	E6-66 Lack of CSR in private companies in China
	E6-67 Not keen, ask for more
	E6-69 Not strong demand
	E6-70 Stable ownership
	E6-71 Not for small business

Table F.5: CSFs from external enabling aspect result shown in NVivo

EF01- "carrot, stick and trumpeter" Policy	E5-38 Government "carrot, stick and trumpeter" policy
EF02 - market demand	E5-39 Healthy market -Competitive, leaning and growing
	E5-41 Solve problem from the source
	E5-42 Policy appetite
EF02 - External drivers	E6-53 Need sufficient funds
	E6-57 Clients need purely financial benefit
	E6-58 Willingness to pay for CSR
EF03 -	E8-25 Added value to clients
	E8-29 meet market requirements
	E8-30 Must buy /have to do
	E8-30 The product is essential
	E10-29 Competitive
	E10-30 High up front cost

Appendix G – List of Distributed PV Policies and Regulations in China

Table G.1: Distributed PV power policies from Aug 2012 and Feb 2014 (Sources: Zhang, 2014)

DSPV policies passed between the second half of 2012 and the first half of 2014.

Category	Time	Agency	Document
Scale and registration management	2013-08-12	NEA	Provisional management measures of distributed power projects
	2013-08-29	NEA	Provisional management measures of distributed solar PV power generation projects
	2014-02-12	NEA	Notice to allocate new construction scale of solar PV projects in 2014
	2013-11-26	NEA	Provisional regulatory measures on the operation of solar PV stations
Tariff, financing and fiscal incentives	2013-08-26	NDRC	Notice to play the role of electricity tariff leverage to promote the healthy development of solar PV industry
	2013-09-10	NDRC	Notice to adjust renewable energy surcharges
	2013-07-24	NDRC	Notice of the generation-based subsidy policy of distributed solar PV and other relevant policies
	2013-09-27	MOF SAT	Notice on the value added tax policy of solar PV power
	2013-11-19	MOF	Notice of issues about the exemption of governmental fund for self-generation and self-consumption distributed solar PV
	2013-08-22	NEA CDB	Opinions on financial services to support distributed solar PV
Market promotion	2013-08-09	NEA	Notice to carry out the construction of demonstration areas of distributed solar PV application
Grid- connection, measurement and settlement	2012-10-26	SGCC	Opinions on providing good services for the grid–integration of distributed solar PV (provisional)
	2012-10-26	SGCC	Opinions on promoting the grid-integration management of distributed solar PV power (provisional)
	2013-02-27	SGCC	Opinions on providing good services for the grid- integration of distributed solar PV (revised)
	2013-02-27	SGCC	Opinions on promoting the grid-integration management of distributed solar PV power (revised)

Table G.2: Major PV power installation related regulation in 2009 and 2010, (Sources: Wang et al., 2011; Li and Wang, 2011)

Date	Name	Focus
March 2009	National subsidy program for building integrated PV (BIPV) applications and rooftop systems (太阳能光电建筑应用财政补助资金管理办法)	Fixed upfront subsidy of 15-20 yuan per watt of installation
July 2009	Rules for model cities in building integrated renewable energy (可再生能源建筑应用城市示范实施方案)	Model cities at district level can receive 50 to 80 million Yuan financial support for large scale installations of building integrated renewable energy On average no more than three cities per province should be supported
July 2009	Golden Sun program (金太阳示范工程财政补助资金管理暂行办法)	Main target areas: – 'User side' grid connected PV power production demonstration projects of large industrial enterprises (BIPV and rooftop) – (Enhanced) electrification of remote and rural areas (off grid) – Integration of wind and PV systems – Large scale on-grid PV power plant projects – Minimum 300 KWp; minimum 20 year use Subsidies of 50 per cent of total investment for on grid projects; 70 per cent of total investment for rural off grid systems; the program was originally limited to support a total of 500 MW in PV installations but later extended to more than 642 MW.
Dec. 2009	REL Revision (in force since April 2010)	Integration of revenues from electricity surcharge and special government funds into the 'renewable energy development fund' Change of 'full purchase (of RE power)' into 'guaranteed full purchase of RE power'

Sources: Wang et al., 2011; Li and Wang, 2011.

Appendix H – Application of BIM for CS1 BIPV Project

Source: CS1-Company B

Journal: Solar Electricity Generation, May 2016

Original Title: BIM 在 BIPV 项目中的应用

BIPV，为 Building Integrated Photovoltaic 的缩写，是光伏建筑一体化的英文简称，也是“建筑产生能源”的新概念建筑，受到全世界普遍高度关注。

BIM，则为 Building Information Modeling 的缩写，是建筑信息模型的简称，是用数字化的建筑组件来表示真实的用来建造建筑物的构件。BIM 技术近年来在新的建筑项目中得到了广泛的应用。

将两项前沿技术结合，既能高效智能的解决光伏方案设计，又可以将信息模型结合手持终端设备来运用到系统建造中，开启绿色、节约、环保、低碳建筑的新篇章。本文将介绍 BIM 技术在 *CS1* 屋顶 BIPV 项目上的应用，这也是国内首个利用 BIM 技术的 BIPV 项目。

图 1：CS1 屋顶 BIPV 完成图

CS1 屋顶光伏发电项目装机容量 3564.90KWp，运用了 13980 块光伏组件，占用办公屋顶面积 50000M^2。考虑组件效率衰减 8‰的前提下，每年可发绿色电力 303.59 万 KWh，运行寿命 25 年，预期总发电量 7589.70 万 KWh。

Appendix I – Project Brief of CS2 Rooftop BIPV Project

光伏应用：屋顶

电池类型：晶体硅（多晶硅）

光伏面积：4800 m²

装机功率：404.8 kWp

年总产能：450 MWh

项目位于东经 113° 46′ ～114° 37′ ，北纬 22° 27′ ～22° 52′ ，年平均日照 1416.2 小时，光照条件较好。该金太阳示范项目建造在建筑屋顶之上，该建筑位置开阔，周边无遮挡，给太阳能的利用带来了便利。项目的设计无需占宝贵的土地资源，并且就地发电，就地使用，减少了电力输送的线路损耗。

该屋顶安装太阳能光伏并网发电系统，系统的方案设计充分考虑了整个光伏系统的屋面承重荷载，抗风压能力、避雷接地系统、系统的负载变化曲率和系统的发电效率等综合因素。系统安装容量 404.905KWp,共采用了 235Wp 多晶硅光伏组件 1723 块,并网逆变器 4 台 100KW 并网逆变器，直流汇流箱 8 台，光伏并网交流配电柜 2 台，接入配电柜 1 台.系统采用并网方式运行，分别并入所在建筑的低压配电网。直流汇流箱根据光伏组串设计要求配置相应的防反保护装置，防止由于热斑等造成光伏组件的损坏.本系统采用了 20 串 11 并和 20 串 10 并两种连接方阵形式。

光伏数据采集监控系统，对光伏系统的全电量以及辐照度,温度等环境参数进行实时的实地监控和远程监控，并有自动故障报警及电能管理等功能.考虑到电缆的使用场所等因素,光伏系统的动力电缆连接线采用 ZR-YJV 交联聚乙烯绝缘交联聚烯烃护套阻燃电力电缆(0.6/1kV).本系统所选用并网逆变器均带有隔离变压器,具有自动切换工作状态及保护功能。该光伏系统年输出电量为 45 万 kWh/year，截止到目前，整个系统运行正常，发电量占该建筑用电负载耗电量的 18%。系统每年可节约煤炭 139 吨，减排 CO_2 约 397 吨，为周边环境带来积极改善作用。

屋面光伏组件的总安装面积为 4800 ㎡。屋面为直立锁边型的金属屋面，根据此种屋面结构，工程师经过计算和反复实验比较，最终确定用铝合金夹具固定于屋面突起的肋上，这样既便于安装又不用穿透屋面而破坏防水。

众所周知，用电高峰期多处于夏季，而此时的光照最强，是一年中光伏系统输出功率最大的时段，并网光伏发电系统在夏季用电高峰时段的每天的发电量超过 2000kWh，大大降低建筑用电对电网供电的需求，较大程度的缓解高峰时段的电网压力。

Appendix G – Case Study Participant Information Sheet and Consent Form

G.1 Case Study Participant Information Sheet

PARTICIPANT INFORMATION SHEET

研究项目参与信息表

- **Project aim 目的：**

The aim of this PhD research programme is to develop a third party investment partnership framework for private sector led low carbon building projects. The concept of the framework is to bring in low carbon services provider who is willing to invest, build and operate low carbon technologies for buildings, eliminating the upfront cost and risk burden to the developers or building owners, providing users with low-running costs, sharing the benefits among project partners.

本次案例合作研究是诺森比亚大学的博士研究项目《开发低碳建筑项目第三方投资合作伙伴框架》的一部分，目的是针对中国私营主导的低碳建筑项目开发一个鼓励采纳低碳技术的第三方投资运营合作模式。该模式可帮助业主／地产开发商解决低碳建筑技术前期投入和运营风险的障碍，由第三方提供建筑低碳产品的投资和运维服务，为用户提供经济的运行费用，实现多方共赢的目的。

- **Case study process and information required 案例研究方法和信息需求：**

In order to develop an adaptable and workable partnership framework, the researcher will apply the conceptual framework developed in the previous stage in real life low carbon building projects in China, testing and refining it through multi case study processes, including interviews, site observation, documents review, financial simulation, and survey etc. Thus projects related financial data, electricity bills, system specifications, operation process, and building information are required.

研究人员将前期研究的概念框架应用于实际案例，用过对项目人员的采访、实地考察、财务分析、问卷调查等多个案例的交叉验证方式，优化和修改该框架。信息收集范围包括但不限于四个方面：投资回报数据、法律合同数据、系统运营数据和风险预测。

- **potential risks involved 潜在风险：**

For business sensitive information, separate confidentiality agreement and additional requirements of usage will be signed to protect the interests of the participants and to eliminate any potential risks. There are no any risks foreseen for other project general data such as building usage, power plant specification, electricity generation and consumption, and participants' opinions etc.

对于商业敏感信息将单独签署保密协议和使用要求，以保护参与方的利益和消除任何潜在风险。其他普通数据如建筑使用情况、电站系统信息、发电和用电量，以及专家提供的意见等没有可见的参与风险。

- **Right 权利：**

Data provider has following rights under the Data Protection Act 1998 where they:

- ✓ can withdraw their permission at any time
- ✓ can ask to access the information at any time
- ✓ know who to contact and how to do so

根据 1998 年数据保护法，数据提供者拥有以下权利：

- ✓ 可以随时退出和撤销许可
- ✓ 可以要求在任何时间访问信息
- ✓ 知道联系谁和联系方式

- **Confidentiality and anonymity 保密和匿名：**

Data will be kept confidential. Project and interviewee names will be anonymised and will not be disclosed.

受访人和案例项目匿名，数据受保护，不会被泄露。

- **Data storage 数据储存：**

Data will be password protected and stored in encrypted devices.

数据储存有密码保护，存储设备要加密。

- **Publishing the results 发表和结果：**

The data obtained will be solely used for the purpose of this research and the processed data will be published without disclosing the project names.

获得的数据将仅用于本项研究。处理后的数据如要发表将不会透露参与人姓名和案例名称。

- **Benefit to participants/data providers 参与方的好处：**

The participants are the potential users and beneficiary of the TpIP framework. Detailed research results of the case studies will be shared with the participants. In addition, the related publications from the projects will be available for the participants.

参与方是该合作框架的潜在使用方和受益方，作为回报案例研究的结果会与参与合作方分享。该结果可为合作方提供未来模式的参考，依据和操作工具。此外，该研究的相关出版物会提供给合作方。

G.2 Case Study Research Participant Consent Form

RESEARCH PARTICIPANT CONSENT FORM

研究参与同意书

Participant organisation:
参与单位：

Project title: Developing A Third Party Investment Partnership Framework For Private Sector Led Low Carbon Building Projects
项目名称：开发由私营主导的低碳建筑项目的第三方投资合作伙伴框架

Researcher's names: Xiaohong Chen
博士研究生：陈晓红

Supervisors' names: Prof. Srinath Perera and Dr. Chika Udeaja
博士生导师：Prof. Srinath Perera and Dr. Chika Udeaja

University: Northumbria University Newcastle
大学：诺森比亚大学，英国纽卡斯尔

Standard statement of participant consent

参与同意声明

I have read and understand the purpose of the study and other details provided in the information sheet
我已阅读并了解研究的目的和信息表中的内容

I have discussed any requirement for anonymity or confidentiality with the researcher.*
我与研究者已讨论匿名和保密要求*

I agree for our projects to be used as case studies for this research **
我同意我们的项目作为研究的案例使用**

The use of the data in research, publications, sharing and archiving has been explained to me
数据在研究、出版物、分享和存档中的使用已向我解释

* See the section below for specific requirements for anonymity or confidentiality
见下页匿名与保密具体要求

**See the section below for agreed case study projects
见下页同意的案例项目

Signed 签名： .... **Date 日期：** ....

Specific requirements for anonymity or confidentiality
匿名与保密具体要求

1. The name of the case study organisation can be published.
   案例公司名称可以发布。

2. The case study project names will be kept confidential.
   案例项目名称需要保密。

3. The person interviewed will be anonymised
   受访人需要匿名。

Case Study Projects
研究案例项目

The following projects are agreed to be used as case studies for this research:
以下项目同意作为本研究的案例项目:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Standard statement by researcher 研究者声明

I have provided information about the research to the research participant and believe that he/she understands what is involved.
我已向研究参与方提供研究信息并相信他 / 她对所参与的研究过程已理解。

Researcher's signature 签名: ____________ **Date 日期:** __________

Appendix K – Case Studies Interview Guidance

The topics and required data are as follows:

Section 1: Project and participants background

- Project information
- Project stakeholders structure and relationship
- Participants' motivations
- Project enabling conditions

Section 2: Refine CSFs in each FLOR aspect

- Financial status of the case projects
- Legal status of the case projects
- Operation and management status of the case projects
- Risk status of the case projects

Section 3: TpIP interventions and predictions

- Problems and challenges experienced by participants
- Suggestions and predictions of intervention
- Projects effectiveness

Appendix L – Cross Case Analysis on FLORE CSFs

L.1 Financial Aspect Cross Case Analysis

Table AK.1: Financial Aspect Cross Case Analysis (Author's own)

Financial CSFs	CS1	CS2	CS3	Findings
F01-Benefits for users	**Saving to clients** 15% discount on market price Carbon reduction requirement	**Benefit to clients** 20% off discount price save 139 tons of coal per year, about 397 tons of CO_2 emissions	**Saving to clients** 15% discount on market price Gain green brand	Benefit to clients Financial savings on small scale PV system are not attractive for users, but still essential Carbon reduction is the main driver
F02-Low financing cost	**Low cost financing** Company B use corporate financing. The sources are bank loans and equity investment. The financing cost close to market benchmark level	**Low cost financing** The sources of the capital are the investor's self-fund and government subsidies No interest to pay	**Low cost financing** Financing sources are from outside of mainland China, relative lower cost	currently, only state-owned companies and large companies are able to get below market benchmark rate

		(This project has short payback period because of low financing cost)		
F03-Acceptable investment payback level	**Attractive investment payback** *IRR=13% Payback period=7years	**Attractive investment payback for investor** Investment payback period < 7 years	**Attractive investment payback** IRR=9 7-9 years	Large industrial building has better return than commercial building IRR>8% <7yesrs
F04 - Access to financing sources	Appropriate financing sources available Equity invest bank loans (short-term) Long-term income to pay short-term loan PV subsidies	**Appropriate financing sources available** Self-equity Golden Sun installation grants	**Appropriate financing sources available** **Availability of bank loan financing** Equity investors, bank loans, crowd funding, subsidies	The current financing means are limited, and not suitable for long-term payback investment. More flexible financing sources should available to meet different needs High liquidity risk when company uses long-term returns to cover short-term loan Crowd funding still has legal issue in China
F05- Government subsidies	**Good subsidies model** 2014 standard: State subsidies (0.42 yuan/unit)	**Good subsidies model**	**Government partnership**	Good subsidies model can encourage high quality and efficiency products,

	to electricity generated for 20 years, plus local government electricity subsidies (0.1yuan/unit) for 10 years	Government Golden Sun Scheme, up front subsidies The Golden Sun model works on this project, but there were also fraud projects get approved	The project works in partnership with the local government	foster competitive and health market, aim for energy parity without subsidies
Other CSF	Guaranteed minimum consumption	Guaranteed minimum consumption	Guaranteed minimum consumption	predictable and stable cash flow

L.2 Legal Aspect Cross Case Analysis

Table AK.3: Legal Aspect Cross Case Analysis (Author's own)

Legal CSFs	CS1	CS2	CS3	Findings
L01 - Credibility and transparency	Choose large, reliable project partners. Use of stock market information disclosure system. Both parties are public listed companies, the company information is transparent and open to public	Choose large, reliable partners. The host party is a world leading retailer The investor is locally based qualified company	Group subsidiaries and industrial alliance, cross-sector partnership Establish industrial alliance working in partnership	**Credibility and transparency** (Use of stock market information disclosure platform for public listed companies)

L02 - Insurance mechanism	Improve quality control Including conditional contract clause to prevent economic lost	Use contract and 3rd party guarantee Including conditional contract clause to prevent economic lost Performance or saving guarantee in EMC	Leaders in specialised field ensure high quality and professionals Including conditional contract clause to prevent economic lost High standard and quality performance, 3rd party certification and assessment	**Insurance mechanism** (Performance guarantee in EMC, and product specification warranty from product supplier)
L03 - Join in government programme	Project filling and local government support Local government demonstration project	Golden Sun Programme provides support, inspection, project approval, and green lights to market	New energy market reform Internal and external interaction- inform and support Working in partnership with the local government. Mutual objectives	Benefit from join in government programme
L 04 - Clear defined ownership and usage rights	Single owner/user building with clear ownership Lease contract for roof usage right	Project building is single owner/user building with clear ownership The investor gains roof usage right through lease contract	Single owner in multi-user building, common management, lease contract	Clear defined ownership and usage rights

	Government filing			
L05 - Roles and responsibilities	Defined in EMC agreement	Roles and responsibilities are clearly defined in EMC agreement The parties have good collaborative flexible relationship particular at the project initiating stage	Defined in EMC agreement and other commissions contracts	Clear defined responsibilities
			Give innovation internet + application opportunity to grow with government inspection	Internet law

L.3 Operational Aspect Cross Case Analysis

Table AK.3: Operational Aspect Cross Case Analysis (Author's own)

Operational CSFs	CS1	CS2	CS3	Refined CSFs
O01 – Information disclosure for matching LCBTs and building stocks	Both parties locate in the same regional, and they are well-known companies. It is easy to gain project and company information.	Both parties locate in the same district, It is easy to gain project and company information.	All parties are industry leader, and are members of locate the industrial alliance.	Information disclosure for matching LCBTs and building stocks

O02- Simplified process for project initiating stage LCBTs	The PV system investor invent a Smart Solar (SS)3.0 application, which can quickly produce a plan and calculate investment return for decision making	The PV system investor Photovoltaic data acquisition and monitoring system, real-time on-site monitoring and remote monitoring of PV system	Central controlled system with end user app Simplified process reduce labour Simplified process for project whole life cycle	Simplified process for project initiating stage LCBTs
O03 - Capability of operation team	The investor are specialised on BIPV, has in house teams for design, EPC and O&M, also established its own R&D centre	The investor are specialised on BIPV, has in house teams for design, EPC and O&M, also established its own R&D centre	Each task allocate to the professional team. The investor works in partnership with leading companies in BIPV design EPC O&M, and ICT, also established its own R&D centre	Capability of operation team
O04- Communication and collaboration	Working in partnership, the investor remotely control and manage the system, integrated the monitoring system into the host management system, routine communication and collaboration effectively reduce risks and cost	The two parties are based in the same area, frequent communication through both online and on-site	Smooth and transparent communications, collaborate on mutual objectives	Communication and collaboration reduce risks and running cost increase efficiency and reduce risk

O05- Mutual benefit objectives	Project performance has impact to the interests of both parties (saving and revenue)	Project performance has impact to the interests of both parties (saving and revenue and)	Members of the industry alliance	Mutual benefit objectives motivate collaborations
O06- Optimise procedure	IT integrated operation system Enable investment to go scale	Remotely controlled monitoring system IT integrated operation system Optimise project procedure though technology innovations and R&D	Centrally controlled monitoring system, big data technology ICT integrated operation system Optimise project procedure though technology innovations and R&D	Technology innovations optimise project procedure
O07- Ensure long-term partnership	Both are large and reliable companies	The host is an international leading companies The investor has track records in it expertise	Established alliance, all parties signed common goal agreement	Secured long-term partnership
O08- Reduce operational cost	Technology innovation and smart management	Technology innovation and remote monitoring R&D investment to reduce operational cost	Central management and remote monitoring Internet+ Energy innovation: FusionSolar system and Energy Blockchin application	Standard and replicable procedures reduce operational cost and enable scale-up

O09- End user engagement	The host is also the end user	The host is also the end user	Blockchin application	End user engagement

L.4 Risk Aspect Cross Case Analysis

Table AK.4: Risk Aspect Cross Case Analysis (Author's own)

Risk CSFs	CS1	CS2	CS3	Refined CSFs and countermeasures
R01 - Long term operation and maintenance risks	The risks of this factor include: the O&M team does not have the capacity leading to poor performance of the system, or the managing company gets bankrupted during the contract period. The risk is allocated to the investor (Company B) who has the expertise and good track records in this fields	The host faces risks: poor performance of the system, O&M company gets bankrupted during the contract period. Choose qualified and skilled company The investor faces risks: Changing tenants, the property sold to difference company.	The host faces risks: poor performance of the system, O&M company gets bankrupted during the contract period. Choose qualified and skilled company The investor faces risks: Changing tenants, the property sold to difference company.	Long-term operation and maintenance risks controlled by reliable and qualified parties

R02 - Financial risks identify key influence variables	Liquidity risks. banks tends to be short-term (1-5 years) Risk of non-performance on the part of host customers (i.e. non-payment of the PV power tariff) Late government subsidies payment	The investor faces risks: non-performance on the part of host customers non-payment of the PV energy bill Grid – connection	The investor faces risks: non-performance on the part of host customers non-payment of the PV energy bill Grid – connection	Financial risks Liquidity risk is unsolved for SMEs; Stable and high energy consumer reduces risk of non-performance of host; Scale-up installed capacity; Guarantee performance contract; Reach to retail parity, no need of subsidies
R03 - Better risk allocation	In current EMC model, the investor carries the entire risk of the project financing, development and O&M.	The investor takes the risk of the project financing, development and O&M. The host takes grid-connection risk and Golden Sun application	The investor takes the risk of the project financing, development and O&M. The host takes grid-connection risk and Golden Sun application	Better risk allocation The investor takes the risks within its expertise, and subcontract non-controllable risks to professional contractors
R04 - Policy risk, identify influence factors and inform policy	This risk relies on external influence, i.e. national and regional government This risk is low for this project, The project is filed in Guangdong DPV filling system and guaranteed a fixed subsidies for 20 years, the	This risk relies on external policies and rules This risk is high for this project. First private commercial BIPV, and first private sector led Golden Sun. No experience to follow.	This risk relies on external policies and rules This risk is high for this project. First private commercial BIPV, and first private sector led Golden Sun. No experience to follow.	Policy risk, unstable temporary and unforeseeable policies, subsidies and implementation are varies in different provinces and cities. National and local policies and incentives are

	energy price in Guangdong province is higher than other province, and policy implementation is relevant prompt.	First time for both project parties and government authorities, time risk if fail	First time for both project parties and government authorities, time risk if fail	improved and more effective through lessons learnt from industry practises
R05 - Market risk, identify market risks for applied LCBT	Solar PV market risk The case study faces: make the solar PV project profitability and lower operational risks and more stable market	Solar PV market risk The case study faces: make the solar PV project profitability and lower operational risks and more stable market	Solar PV market risk The case study faces: make the solar PV project profitability and lower operational risks and more stable market	Market risk Innovations in technology and management model Innovative financing channel Reform in energy demand-side market (External enabling conditions)
R06 - Risk control measures	Grid-connection service guaranteed Use of BIM	Grid-connection service may not be well implemented.	Contract with utility company Control managed system	Risk control measures See countermeasures for each risk factor above
R07 - Lack of integrity	The case study participants are reputable listed companies with less integrity risks	The case study participants are reputable listed companies with less integrity risks	The case study participants are reputable listed companies with less integrity risks	Lack of integrity Trust and reliable project partners

L.5 External Enabling Conditions Cross Case Analysis

Figure AK.1: External Enabling Conditions Cross Case Analysis (Author's own)